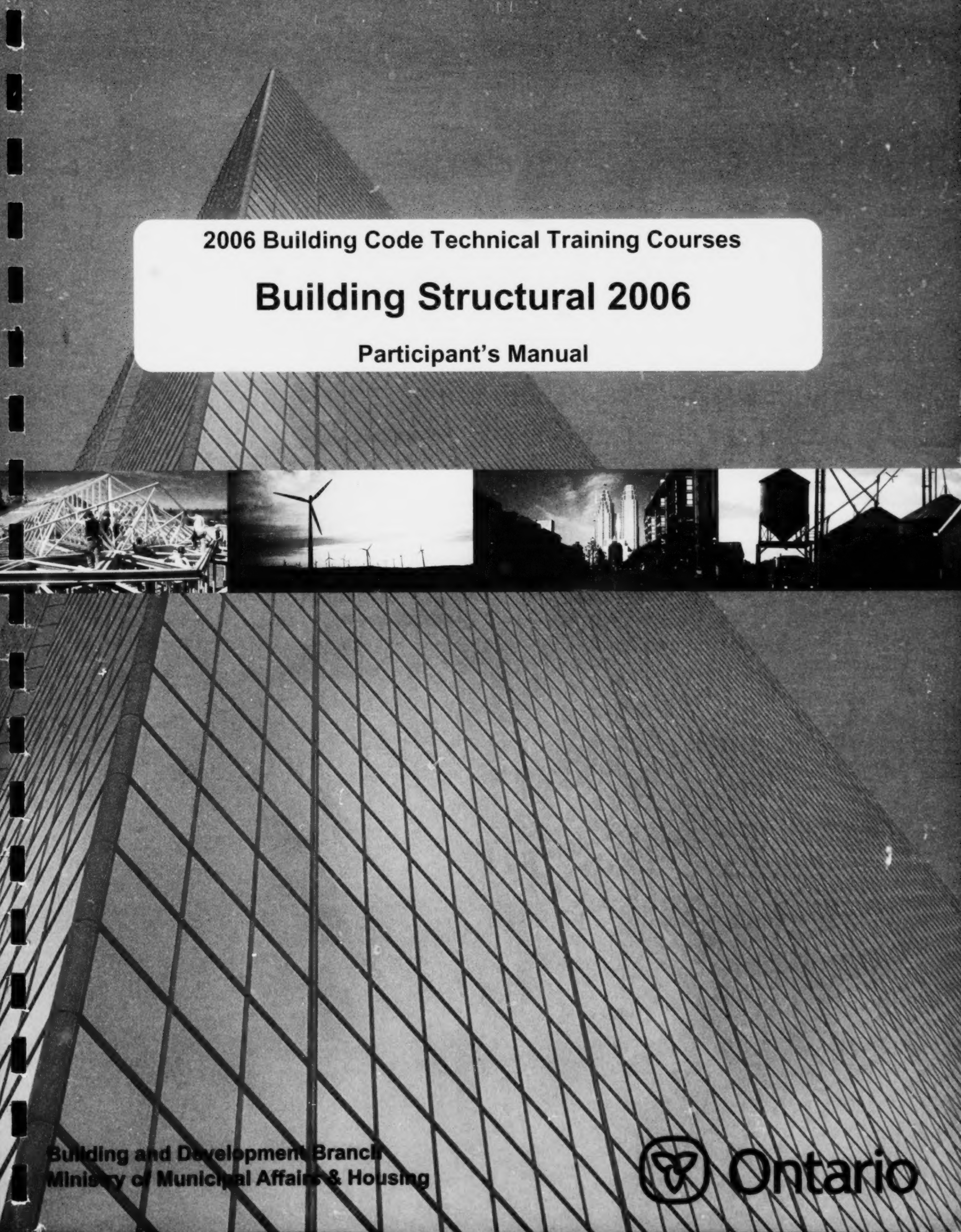

2006 Building Code Technical Training Courses

Building Structural 2006

Participant's Manual

Building and Development Branch
Ministry of Municipal Affairs & Housing

Ontario

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Ontario Building Code
Technical Training Courses

Building Structural 2006

PARTICIPANT'S MANUAL

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MODULE 1

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1.0 INTRODUCTION

As required by Sections 15.11 and 15.12 of the Building Code Act, it is required that all building officials, certain classes of designers, registered code agencies and persons engaged in the business of sewage systems have mandatory qualifications as set out in the Building Code. These qualifications require that individuals successfully complete an examination program administered or authorized by the Ministry of Municipal Affairs and Housing.

The specific requirements for the mandatory qualifications are given in Division C Part 3 of the Ontario Building Code 2006, O.Reg. 350/06 (as amended).

1.1 COURSE SCOPE AND OBJECTIVES

The objective of this course is to help the reader understand the requirements of the 2006 Ontario Building Code Division B, applicable to building structures, and to assist candidates with preparation for the qualification examination.

Completion of this course alone may not be sufficient preparation for the examination, for all persons. Additional independent reading and review of the Code may be required.

Neither this course, nor the qualification examination, address structural engineering principles and design methods. Additionally, the various documents referenced by the Building Code do not form part of this course, nor the qualification examination.

This course is not intended to be a textbook on the structural design of buildings, but is rather an introduction and overview of the structural requirements as found in the Building Code. While it would be beneficial for persons undertaking this course to have a prior knowledge of structural design, such knowledge is not necessary to be successful in the examination.

The course is geared to assist the candidate with the development of the required skills of finding, understanding and applying the structural provisions of the Building Code. These skills are necessary to be successful in passing the qualification examination.

Recognizing that some readers will have greater familiarity with either Part 4 or Part 9, approximately equal emphasis will be placed on these parts of the code. The course will also address limitations of Part 9 in the design and construction of buildings, and will identify situations where Part 4 must be used for Part 9 buildings.

References made throughout this course to the abbreviation "OBC" are intended to refer to the 2006 Ontario Building Code, O.Reg. 350/06, as amended to O.Reg. 137/07. The use of the terms "Building Code", or "Code" in this course also refer to the above noted regulation.
(The use of "OBC" in this course should not be confused with "objective-based code".)

Unless otherwise noted, all Code references within this course are intended to refer to Division B.

1.2 EXAMINATION SYLLABUS AND EXAMINATION FORMAT

An examination syllabus published by the Ministry of Municipal Affairs and Housing gives examination candidates the specific topics that will be covered in each examination. The syllabi for "Building Structural" is found on their website:

http://www.obc.mah.gov.on.ca

under the headings: "Qualification & Registration / Examination Syllabi".

Questions on the Ministry's exams are all multiple choice. They have been chosen to address Building Code requirements based on the "**difficulty**", "**importance**" and "**frequency**" of the requirement. The function of the questions is to test the ability of the candidate to find, understand or apply the Code requirements.

Sample examination questions are available on the Ministry's website. Some of the exercises in this course use the same multiple choice format as the examination.

Examinations do not necessarily include all of the subject matter of the syllabus. Instead, the syllabus defines the pool of knowledge that a practitioner is expected to know. Each examination is made up of representative questions drawn from the pool. Not all examinations will be identical, even within the same exam sitting.

Further, some questions may require candidates to consider provisions that lie outside of the syllabus, but are directly referenced by provisions contained within the syllabus.

The subject matter of this course approximately parallels the subject matter of the 2003 Building Structural Syllabus. In general, this course focuses on Volume 1 Division B of the 2006 Building Code.

1.3 LEARNING OUTCOMES

The course has been designed to introduce or increase (where applicable) a practitioner's knowledge of the Code and to hone skills in terms of their ability to **FIND** (search the Code and identify non-familiar Code provisions), **UNDERSTAND** (to comprehend the language, structure and intent of a Code provision), and **APPLY** the Code provision(s) using case examples, situations and scenarios.

The Ministry of Municipal Affairs and Housing also provides more comprehensive courses for practitioners wishing to obtain more detailed training in the use and application of the Building Code and a number of its referenced standards.

For information on the available courses, refer to the following website:

http://www.obc.mah.gov.on.ca

under the heading "Training".

1.4 COURSE FORMAT

This course is organized in twenty Modules, and is intended for those who desire to become more proficient in applying the provisions of the requirements applicable to Building Structures.

The subject matter of this course is presented in a sequence to assist understanding of the Code, and does not necessarily parallel the order of the provisions and requirements as set out in the Code.

Participants should be aware that the course format and content has been developed based on consultation between the Ministry of Municipal Affairs and Housing and stakeholders.

1.5 PURPOSE OF THE EXERCISES

Every Module contains a number of exercises. Each exercise is designed to help you to identify, understand and apply the requirements of the Building Code and their effect on *building* structures.

The format of the exercises are either fill-in-the-blank or multiple choice. You will also be asked to complete charts and tables that can later be used as job aids in fulfilling your professional responsibilities.

You will also be required to indicate the OBC reference for your answers. Pay attention to the detail of the reference, as some of the exercise questions will require the use of more than one Code reference.

As you go along, you are encouraged to modify and enhance your personal copy of the Code by adding any handwritten notes (such as cross-references or explanatory information) that may assist you.

When reference is made to specific provisions of the Building Code at the beginning of an exercise, you may find it useful to review those references before attempting the exercise.

1.6 COURSE RESOURCES

Your participation, with support from the Facilitator, the Building Code, and the experiences, ideas, and comments of your fellow students are the primary resources of this course. The objective of the course integrates your education, prior training and on-the-job experience, as well as those of your peers. It is important that you actively participate. Please be respectful of the other students by remaining quiet during the set assignments. Noise can be very distracting for some.

For each question or task that is assigned to your table-group, you will select a spokesperson who will print the agreed upon answer on the flipchart. When asked by the Facilitator, the spokesperson will explain the group's answer, which form the basis for class discussion.

The course requires the latest edition of the following documents:

- Building Code Act, 1992, as amended,
- Volumes 1 and 2 of The Building Code, 2006 (O.Reg. 305/06), as amended, and
- The Supplementary Standards to the Ontario Building Code 2006 are included in Volume 2.

1.7 INTRODUCTION – 2006 BUILDING CODE COMPENDIUM

The Ontario Building Code is a regulation made under the Building Code Act. This edition is prepared for purposes of convenience only and contains additional explanatory material. For accurate reference, recourse should be had to the Official Volumes.

The Code is essentially a set of minimum provisions respecting the safety of buildings with reference to public health, fire protection and structural sufficiency. It is not intended to be a textbook on building design, advice on which should be sought from professional sources. Its primary purpose is the promotion of public safety through the application of appropriate uniform building standards.

1.7.1 Organization Of The Building Code

The Code is organized into two volumes. Volume 1 has three divisions, as described in Section 1.1.1 of Division A of the Code:

Division A – Compliance Objectives and Functional Statements

This Division sets out the compliance and application requirements and the scope of the three Divisions.

Division A describes the overall goals that the Code's provisions are intended to achieve. *Functional statements* describe the functions that a *building* or its components must perform to fulfill the *objectives*. At least one *objective* and one *functional statement* are linked to each Code technical requirement to help users better understand the reason why a particular requirement must be met and to help them evaluate alternative solutions.

Division B - Acceptable Solutions

This Division provides the acceptable solutions (or prescriptive and performance technical requirements) of the Code. In general, most designs will be carried out under the provisions of Division B.

The rules governing the applicability of the various Parts of Division B are set out in Part 1 of Division A.

Division B is divided into 12 Parts. In general, this course will focus on the structural requirements of Division B.

Division C – Administrative Provisions

The administrative requirements of the Code are consolidated in Division C. Included are the requirements for qualification.

Each Division is divided into Parts, and a decimal numbering system has been used to identify particular requirements. The first number indicates the Part of the Code, the second, the Section in the Part, the third, the Subsection and the fourth, the Article in the Subsection. An Article may be further broken down into Sentences (indicated by numbers in brackets), and the Sentence further divided into Clauses and Subclauses. These are illustrated as follows, using an example from Division B:

4	Part
4.1.	Section
4.1.8.	Subsection
4.1.8.11.	Article
4.1.8.11.(3)	Sentence
4.1.8.11.(3)(d)	Clause
4.1.8.11.(3)(d)(i)	Subclause

In reading the Code, references may be made to other provisions of the Code. As stated in Article 1.1.1.4, of Division A, any cross-references are intended to be within the same Division, unless stated otherwise stated.

1.7.2 Defined Words, Terms And Phrases

Throughout the Code and this course, various words and terms have special meanings. Often these meanings may differ from those used in common language.

Defined terms in the Building Code appear in ***italics***, and definitions for such terms can be found in Article 1.4.1.2 of Division A. Additional definitions of importance are provided in Section 1 of the Building Code Act.

The Division A definition always applies unless the word, term or phrase has a special purpose definition listed elsewhere.
An example of this is the term "soil":

- The definition for *soil* in Division A Clause 1.4.1.2.(1)(b) is: Soil means, except for the purposes of Part 8 of Division B, a portion of the earth's crust that is fragmentary or such that individual particles of a dried sample may be readily separated by agitation in water, and includes boulders, cobbles, gravel, sand, silt, clay and organic matter.
- However, in Division B, Part 8 (Sewage Systems), soil has a different meaning, as stated in Article 8.1.1.2.(1):
  Soil *means in-situ, naturally occurring, unconsolidated mineral or organic material, at the earth's surface that is at least 100 mm thick and capable of supporting plant growth, and includes material compacted or cemented by soil forming processes, but does not include displaced materials such as gravel dumps, mine spoils, or like deposits.*

For consistency with the Building Code, defined terms are shown in this course in ***italics***.

1.7.3 Non-Defined Words, Terms And Phrases

For words and phrases used in the Code that are not defined, Article 1.4.1.1 of Division A dictates these words have the meanings which are commonly assigned to them in the context in which they are used in this Code, taking into account the specialized use of terms with the various trades and professions to which the terminology applies.

For those who are not familiar with construction terminology relevant to *building structures*, help is available in the following publications:

- Appendix A of the Building Code
- Glossary of Housing Terms, by the Canada Mortgage and Housing Corporation (CMHC)
- Canadian Wood-Frame House Construction, by CMHC
- Various structural engineering texts.

1.7.4 Symbols And Other Abbreviations

The meaning of Symbols and Abbreviations used in the Building Code can be found in Table 1.4.2.1. of Division A.

For example, in Division B, the letter 'h' means 'hour' in Sentence 9.10.9.11.(1) and 'hours' in Sentence 9.10.9.11.(2). The expression '1 in 2' means a slope of 1 vertical unit to 2 horizontal units.

1.7.5 Abbreviations Of Proper Names

Subsection 1.3.2 and Table 1.3.2.1 of Division B list the abbreviations of proper names that appear in the Code. See Division A, Section 1.5, "Referenced Documents and Organizations".

For example, in Division B, Clause 9.20.2.1.(1)(g) refers to "CAN3", and Clause 9.20.2.1.(1)(h) to "CSA", both being abbreviated names of the Canadian Standards Association.

1.7.6 Dealing With 'And'

The word '**and**' found at the end of the second last Clause of a Sentence with multiple Clauses means that the requirements of every Clause apply to the Sentence.

Example:

In the Building Code, Sentence 4.1.3.5.(1) reads:

> In proportioning structural members to limit serviceability problems resulting from deflection, consideration shall be given to,
>
> (a) the intended use of the building or member,
>
> (b) limiting damage to non-structural members made of materials whose physical properties are known at the time of design,
>
> (c) limiting damage to the structure itself, and
>
> (d) creep, shrinkage, temperature changes and prestress.

1.7.7 Dealing With 'Or'

The word '**or**' found at the end of the second last Clause of a Sentence with multiple Clauses means that the requirement of the Sentence is satisfied by any Clause as applied individually.

For example, Division B, Sentence 9.15.2.4.(1) states:

> Foundations of wood frame construction shall conform to,
>
> (a) CAN/CSA-S406, "Construction of Preserved Wood Foundations", or
>
> (b) Part 4.

1.7.8 Rules and Exceptions of The Code

The Building Code is structured into a number of Rules that apply without exception.

For example, Sentence 9.3.2.5.(1) states, without exception:

Moisture content of lumber shall be not more than 19% at the time of installation.

At other times, the user of the Code has to consider a general rule and exceptions as they apply. Consider the requirements for anchorage of columns and posts in Article 9.23.6.2:

(1) Except as provided in Sentences (2) and (3), exterior columns and posts shall be anchored to resist uplift and lateral movement.

(2) Except as provided in Sentence (3), where columns or posts support balconies, decks, verandas and other exterior platforms, and the columns or posts extend not more than 600 mm above finished ground level, the supported joists or beams shall be,

  (a) anchored to a *foundation* to resist uplift and lateral movement, or

  (b) directly anchored to the ground to resist uplift.

(3) Anchorage is not required for platforms described in Sentence (2) that,

  (a) are not more than 1 storey,

  (b) are not more than 55 m^2 in area,

  (c) do not support a roof, and

  (d) are not attached to another structure, unless it can be demonstrated that differential movement will not adversely affect the performance of that structure.

When the Code spells out a general rule and exceptions thereto, conformity with the Code is obtained by complying with EITHER the general rule OR the exception thereto. In such cases, the user is cautioned to read the entire Article of the Code, before reaching conclusions regarding the applicability of any portion of that Article.

1.7.9 Tables, Text And Footnotes

Whenever you are called upon to use a Table in the Building Code, you have to consider the text associated with the Table and the footnotes.

For example, Table 4.1.5.3 forms part of Sentence 4.1.5.3.(1). One of the notes to Table 4.1.5.3, Note (3), directs us to Sentence 4.1.5.7.(1), which provides additional requirements for loading due to "intended use".

1.7.10 Supplementary Standards

By virtue of Paragraph 34.(1) 9. of the Building Code Act, the "2006 Building Code Supplementary Standards" form an integral part of the Code.

Table 1.3.1.2 of Division B lists these Standards, and includes Code references indicating where they apply. The Supplementary Standards are further referenced from within the Code (such as by Sentence 3.6.1.5.(1) for example.

In preparing for the qualification examination, the reader should be aware that the content of those Supplementary Standards identified in the Building Structural syllabus forms part of the study material.

1.7.11 Reference Documents

Subsection 1.3.1 and Table 1.3.1.2 of Division B list additional reference documents and standards that form an integral part of the Building Code. The specific editions of these documents are the only versions applicable to the Code. These documents are further referenced from within the Code (such as by Sentence 4.3.1.1.(1), for example).

In preparing for the qualification examination, the reader should be aware that the content of the reference documents does not form part of the study material.

1.7.12 Appendices

Appendix A is organized under three headings as follows:

- Explanatory Material for Division A
- Explanatory Material for Division B
- Explanatory Material for Division C

Appendix B contains "Imperial Conversions of Metric Values" and "SI Units and Their Multiples".

The appendices to the Building Code have been prepared for convenience only, and contain information that does not form part of the Code. The appendices are not intended to limit the ways by which compliance with Code requirements can be achieved.

However, the Appendices do contain valuable and important information necessary to effectively make use of the Building Code for structural design of *buildings*.

An example of this is Article 4.1.7.1 of Division B, entitled "Wind Loads". This Article refers to Appendix A, and sentences within Appendix A, such as A-4.1.7.1.(1), refer to the User's Guide – NBC 2005, Structural Commentaries (Part 4 of Division B).

There are numerous references from the Code to the User's Guide through Appendix A. However, it should be recognized that the User's Guide does not form part of the examination syllabus.

1.8 BUILDING STRUCTURES - SCOPE AND APPLICATION OF DIVISION B

Individual requirements within Division B do not apply to every *building*. The rules for the application of each of the 12 Parts of Division B to a particular *building* are found in Subsection 1.1.2 of Division A.

For instance, Sentence 1.1.2.1.(1) informs us that Parts 1, 7 and 12 apply to every *building*.

Sentence 1.1.2.4.(1) tells us that Part 9 would apply to *buildings* of *residential* and *mercantile occupancies*, of three *storeys* or less in *building height* and having a *building area* not exceeding

600 m^2. However, Clause 1.1.2.2.(2)(b) indicates that the structural design of a *building* of *residential or mercantile occupancy* would be governed by Part 4 instead of Part 9, if the *building area* exceeded 600 m^2 or the *building height* exceeded 3 *storeys*.

From the above example, it should become very clear that one does not jump from Part 9 to Part 4, or from Part 4 to Part 9, unless the Code specifically provides direction to that effect.

Another example is the snow loading requirements for certain elements in "Part 9" *buildings*. Sentence 9.4.2.2.(3) informs us that the snow loads for special roof trusses spanning more than 6 metres are to be determined using Subsection 4.1.6. Thus, in this instance, the requirements of Part 4 must be applied to a *building* regulated by Part 9 of the Building Code.

However, sometimes Part 9 provisions must be used in the design of *buildings* using Part 4. Consider the requirements of Sentence 4.3.1.3.(1). We are informed that in areas know to be infested with termites, wood used in structures designed under Part 4 shall comply with the requirements of Articles 9.3.2.9, 9.12.1.1 and 9.15.5.1. Thus in this instance, a Part 9 provision is deemed to form part of a Part 4 requirement.

In general, however, the provisions of Part 9 are not applicable to Part 3 *buildings*. According to Clause 1.1.2.2.(2)(b), the structural systems of Part 3 *buildings* must be designed using Part 4.

In contrast, Clause 9.4.1.1.(c) allows Part 4 to be used in the structural design of Part 9 *buildings* at any time.

The various Modules of this course will further discuss the applicability of Part 4 and 9 to *building* structures.

1.9 CLOSING COMMENTS

In preparation to attend this course, you are asked to complete as many of the exercises as you can. During the delivery of the course, you are asked to obey the **STOP** signs.

The Facilitator will provide guidance to keep the course moving. It is acknowledged that completion of the course within the allocated time will be a challenge, and will require the cooperation and commitment of everyone.

Bring your questions and comments to the course and participate in all the discussions. Reading ahead on your own time may be necessary should you find that you have difficulty with some of the material.

Your evaluation of the course and comments on its contents will be collected during the session. Your input is important, it enables the Ministry of Municipal Affairs and Housing to keep the course current, accurate and relevant and to meet your needs. In preparation, you are asked to note your comments on plain paper. They will be collected at the end of the course. You will also be asked to evaluate the Facilitator and the facilities where the course is being held, at the end of the course.

Unlike the course, for the qualification examination, you will not be asked to provide Code references to support your answers. Nevertheless, you are strongly encouraged to find the supporting part of the Building Code. Remember, you need to find a requirement before you can understand and apply it.

STOP End of Module 1

MODULE 2

SCOPE AND GENERAL REQUIREMENTS

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2.0 INTRODUCTION

This Module focuses on how to find information in the Building Code, and how to determine which portions of Division B of the Code apply to the different types of *building* structures.

2.1 OBJECTIVES

Upon completion of this Module, participants will be able to:

- Find information and defined terms in the Building Code,
- Explain how to determine which Parts of the Building Code apply to different types of structures,
- Apply the concept of *building area, building height* and *occupancy* type in classifying *buildings,*
- Describe where to apply Part 4 and Part 9 in the structural design of *buildings,*
- Identify structures specifically designated for design under Part 4,
- Find climatic and seismic data necessary for the structural design of *buildings.*

2.2 FINDING INFORMATION IN THE BUILDING CODE

Subsection 1.1.2 of Division A provides important direction on the Parts of Division B that are applicable to any particular situation.

Each Part of Division B contains a table of contents, which assists in locating specific Code requirements. The index to the Code is very helpful in quickly locating specific information, but it is important to understand that the index does not indicate whether the information applies to a particular situation, nor is the index comprehensive.

Exercise #2-1

Complete the following exercise, then discuss the answers with your group.

1. For each of the following, find and state the Sentence(s) of Division B that give the applicable Code provisions. (Hint: use the Index of your Building Code)
   a) Design loads for installation of a "*grab bar*" in a water closet stall of a "Part 3" building

      ____

      ____

   b) Design requirements for aluminum structures

      ____

   c) Maximum spacing of crack control joints in *foundation* walls for a Part 9 *building*?

      ____

STOP

2.3 WHAT IS A BUILDING?

The Building Code Act defines the term *building* as follows:

(a) a structure occupying an area greater than ten square metres consisting of a wall, roof and floor or any of them or a structural system serving the function thereof including all plumbing, works, fixtures and service systems appurtenant thereto,

(b) a structure occupying an area of ten square metres or less that contains plumbing, including the plumbing appurtenant thereto,

(c) plumbing not located in a structure,

(c.1) a sewage system, or

(d) structures designated in the building code.

The subject of "designated structures" will be discussed in detail later in this Module.

The Act also gives the following important definitions:

> "**construct**" means to do anything in the erection, installation, extension or material alteration or repair of a building and includes the installation of a building unit fabricated or moved from elsewhere and "construction" has a corresponding meaning.
>
> "**demolish**" means to do anything in the removal of a building or any material part thereof and "demolition" has a corresponding meaning.

The requirements of the OBC apply to the construction and to the demolition of buildings.

2.4 BUILDING AREA, HEIGHT AND OCCUPANCY

In applying the Building Code to any particular *building*, it is necessary to start by determining which Parts of the Code are applicable to that specific *building*.

In general, the structural design and construction of all *buildings* and other designated structures must comply with the requirements of Part 4 of the Code. However, in certain circumstances, the design of "houses and small buildings" may be carried out using the provisions of Part 9 of the Code.

The determination of which types of *buildings* may be considered "Part 9 buildings" is based on *building area*, *building height* and type of *occupancy*. Please take a moment to review these definitions in Clause 1.4.1.2.(1)(b) of Division A. Care should be taken not to confuse such terms as *gross area* and *floor area* with *building area*.

Also important in the classification of *buildings* is the type of *occupancy* of the *building*, which pertains to the degree of hazard associated with the *building* usage. Terminology pertaining to *occupancy* is also defined in Clause 1.4.1.2.(1)(b) of Division A.

In reading Article 1.1.2.2, it will become apparent that Part 4 applies to all Part 3 *buildings*.

Exercise #2-2

Read all of Articles 1.1.2.2 and 1.1.2.4 of Division A. Complete the following exercise, and when complete, discuss the answers with your group.

Which of the following *buildings* must be constructed using the provisions of Part 9
of Division B?

1. Two-*storey* single-family residence, having overall maximum horizontal dimensions of 4.0 meters x 12.0 meters?

   ☐ Part 9 ☐ Parts 3 and 4

   OBC Reference(s): ________________________

2. Three-storey single-family residence, with *basement*, having overall maximum horizontal dimensions of 4.0 meters x 12.0 meters?

   ☐ Part 9 ☐ Parts 3 and 4

   OBC Reference(s): ________________________

3. One-storey funeral home and chapel, having overall maximum horizontal dimensions 4.0 meters x 12.0 meters?

   ☐ Part 9 ☐ Parts 3 and 4

   OBC Reference(s): ________________________

STOP

2.5 DESIGNATED STRUCTURES

As discussed above, the Building Code Act includes "designated structures" in the definition of the term *building*. Article 1.3.1.1 of Division A identifies such designated structures, and Clause 1.1.2.2.(2)(c) of Division A requires that these be designed and constructed under the provisions of Division B, Part 4.

Signs and sign supporting structures represent a special case. According to Clause 1.1.2.2.(2)(c) of Division A, self-supporting signs are considered designated structures. However, Clause 1.1.2.2.(5) of Division A directs the user of the Code to Division B, Section 3.15, for signs that are supported by a building.

In Division B, Article 3.15.3.1 states that sign structures must be designed in accordance with Part 4. However, it should be recognized that certain types of signs are exempted from the provisions of Section 3.15, as stated in Article 3.15.1.2. If a sign structure is of a type that allows an exemption under Article 3.15.1.2, then that sign would not require design under Part 4.

Exercise #2-3

Read the requirements of Article 1.3.1.1 and Clause 1.1.2.2.(2)(c) of Division A. Complete the following exercise, and then discuss the answers with your group.

Which of the following situations are "designated structures" to which the structural provisions of Part 4 of Division B apply?

1. A 2.7-meter diameter television dish antenna, with a face area of 5.7 m^2, on the roof of a restaurant.

   Designated structure? ☐ Yes ☐ No

   Part 4 design required? ☐ Yes ☐ No

   OBC Reference(s): ______________________

2. Retaining walls, on each side of an exterior stair that provides access to the *basement* of a store entrance, in which the *basement* is 2000 mm below finished exterior grade.

   Designated structure? ☐ Yes ☐ No

   Part 4 design required? ☐ Yes ☐ No

   OBC Reference(s): ______________

3. An exterior fuel storage tank regulated by the Technical Standards and Safety Act, 2000.

   Designated structure? ☐ Yes ☐ No

   Part 4 design required? ☐ Yes ☐ No

   OBC Reference(s): ______________

4. A plastic-faced illuminated sign, mounted on a Part 3 *building*, not exempted by Article 3.15.1.2 of Division B.

   Designated structure? ☐ Yes ☐ No

   Part 4 design required? ☐ Yes ☐ No

   OBC Reference(s): ______________

   Comments: ______________

   ____

   ____

STOP

2.6 DOCUMENTS REFERENCED IN THE CODE

Portions of Division B, such as Part 9, are primarily prescriptive in nature, and give specific requirements for materials and/or structural assemblies. Other portions of the Code, such as Section 4.3, address similar requirements by means of reference to specific documents published by independent agencies.

Section 1.5 of Division A gives the requirements for the applicable editions or versions of any document referenced by the Building Code, and must be read in conjunction with Subsection 1.3.1 of Division B. As stated in Sentence 1.3.1.1.(1), the documents referenced by the Code shall include all amendments, revisions and supplements effective to May 31, 2006, unless otherwise stated in the Code. **It is not correct to assume that the most recent version of any Standard or reference document will have been adopted by the Code.**

It is important to recognize when the documents listed in Subsection 1.3.1 and Table 1.3.1.2 of Division B apply. This is best illustrated by an example:

- Table 1.3.1.2 lists CSA Standard S304.1-04, titled "Design of Masonry Structures"
- Column 4 of this Table indicates that S304.1-04 is referenced by Table 4.1.8.9 and Sentence 4.3.2.1.(1), but there is no cross-reference to Part 9 from this Table.
- As indicated in Sentence 4.3.2.1.(1), S304.1-04 does apply to masonry in *buildings* designed using Part 4.
- Section 9.20 includes requirements for masonry, but it does not specifically refer to S304.1-04. As such, the provisions of S304.1-04 do not necessarily apply to structures designed using the provisions of Section 9.20.
- However, should the designer choose to design the masonry in a Part 9 *building* using Part 4 provisions, as is allowed by Subclause 9.4.1.1.(1)(c), then that design would need to fully comply with S304.1-04, as would be required by Sentence 4.3.2.1.(1).

In the case of a conflict between the Code and any reference document, Article 1.5.1.2 of Division A states that the Code provisions shall govern.

It should be recognized that the Building Structural examination syllabus does not include the specific technical provisions within the documents referenced by the OBC. **The examination will not test knowledge of the content of referenced documents.** However, the syllabus does include the requirement to be familiar with which reference Standards are applicable to a particular structural situation.

Exercise #2-4

Complete the following exercise, then discuss the answers with your group.

1. In Table 1.3.1.2 of Division B, the "Issuing Agency" CWC refers to the Canadian Wood Council, as indicated by Table 1.3.2.1.
   What specific Code provision permits the use of CWC's "Engineering Guide for Wood Frame Construction"?
   a) Sentence 4.3.1.1.(1)
   b) Clause 9.4.1.1.(1)(b)
   c) Sentence 9.23.2.1.(1)
   d) The National Farm Building Code of Canada
   OBC Reference(s): ________________

2. In applying the Building Code, you have discovered that there is a conflicting requirement between a specific provision in Part 9 of Division B, and the provision of a specific document listed in Table 1.3.1.2 of Division B. What should you do?
   a) Apply the Part 9 provision
   b) Apply the provision of the reference document
   c) Apply the most restrictive provision of a) and b)
   d) Seek interpretation from the *Chief Building Official.*
   OBC Reference(s): ________________

STOP

2.7 CLIMATIC DATA FOR STRUCTURAL DESIGN

Volume 1 Subsection 1.1.2 of Division B, and Supplementary Standard SB-1, which is found in volume 2, provide climatic and seismic design data necessary for the design of *buildings*.

Data is tabulated for a representative number of locations in Ontario. The "introduction" to SB-1 provides guidance on the use of design data for municipalities not listed in Table 1.2 of SB-1.

Later Modules of this course will refer to this climatic data, in the determination of structural loadings for *buildings*.

Exercise #2-5

With reference to Supplementary Standard SB-1, answer the following questions then discuss your answers with the group.

e)

1. Using Table 1.2 of SB-1, list the five general classifications of climatic/seismic data that are considered in the design of *buildings*:

   a) ______________________________

   b) ______________________________

   c) ______________________________

   d) ______________________________

   e) ______________________________

2. If Table 1.2 does not list the climatic and seismic information for a particular municipality where you are designing a *building*, what should you do?

   a) Obtain the information from the Atmospheric and Environmental Service, Environment Canada

   b) Interpolate the data for the nearest municipalities

   c) Use the most severe data for all locations in Ontario

   d) Discuss with the Chief Building Official.

   OBC Reference(s): ____________

3. For Alliston, the 1-in-50 year return hourly wind pressure is given in Table 1.2 as 0.33 kPa.
Using Table 1.1, what is the wind speed that corresponds with this pressure?

   a) 0.33 m/s

   b) 18.4 m/s

   c) 22.6 m/s

   d) none of the above

   OBC Reference(s): ______________

STOP End of Module 2

MODULE 3

STRUCTURAL DESIGN USING DIVISION B, PART 4

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3.0 INTRODUCTION

In this Module, we will learn the general requirements for structural design using Division B, Part 4, review the types of specified loads and effects and identify the Code requirements for addressing these. In this Module, all references to Part 4 are with respect to Division B of the Code, unless stated otherwise.

As discussed in Module 2, *buildings* not within the scope of Part 9 must have their structural systems designed using Part 4. As will be seen in a later part of this course, *building* renovations using Part 11 may also require assessment or design using Part 4. (Similarly, changes in use, regulated by Part 10 of the Code, may also require structural assessment or design using Part 4.)

3.1 OBJECTIVES

Upon completion of this Module, participants will be able to:

- State the alternative acceptable basis for structural designs under Part 4
- Describe the different types of structural loads
- Know how to classify *buildings* by their Importance Category
- Apply the required structural design criteria, including specified loads and strength, deflections, vibrations and fatigue
- Recognize the Code requirements regarding the use of limit states design
- Describe the use of Companion Action loading in structural design
- Calculate and verify load combinations for given loading scenarios

3.2 DESIGN REQUIREMENTS AND BASIS

The overall requirements for the design of *building* structures, structural members and connections are given in Article 4.1.1.3. Article 4.1.1.4 identifies the acceptable basis for structural design using the Code.

Exercise #3-1

Read Articles 4.1.1.3 and 4.1.1.4, complete the following exercise, then discuss the answers with your group.

1. Which of the following is not required by the Code to be considered in the design of *buildings*, structural members and connections?
    a) Temporary loads that may occur during construction
    b) Specified permanent loads on the *building*
    c) Serviceability, as defined in Clause 4.1.3.1.(1)(a)
    d) Loads that are not reasonably expected during the anticipated service life of the *building*

   OBC Reference(s): ______________________

2. When is it permissible to exceed the "specified load" of a structural member during the construction period?
    a) With the written permission of the *Chief Building Official*
    b) Analysis has confirmed that the member would not be impaired
    c) Precautions have been taken to ensure that no damage or distortion would occur
    d) Never

   OBC Reference(s): ______________________

3. Which of the following is not an acceptable basis for the design of *buildings* and their structural members?

   a) Compliance with the design procedures of Part 4

   b) Load testing of full-scale prototypes.

   c) Satisfactory performance of a similar structure for over 50 years.

   d) Analysis of the structure based on generally established theories.

   OBC Reference(s): ________________

4. Which of the following must be designed in accordance with CSA Standard S37?

   a) Temporary formwork and falsework for a *building*

   b) Communications towers designated under Division A, Subclause 1.3.1.1.(1)(a)(i)

   c) Permanent structural members and their connections

   d) Model analogues

   OBC Reference(s): ______________________

STOP

3.3 SPECIFIED LOADS AND EFFECTS

A load may be defined as "a force or other action that result from the self-weight of all building materials, environmental effects, occupants and their possessions, differential movements, and restrained dimensional changes."

Subsection 4.1.2 identifies the loads that must be considered and accounted for in the design of *buildings*, and provides specific terminology for the classification of loads. In a later section of this Module, it will become apparent that the classification of loads is particularly important in determining the actual design forces for *buildings*.

"Specified loads" are defined in Clause 4.1.3.1.(1)(b) as those set out in Table 4.1.2.1.A.

Exercise #3-2

Read Article 4.1.2.1, Article 4.1.2.2 and the definitions in Sentence 4.1.4.1.(1). Review the definitions in Division A, Section 1.4 that correspond with the italicized text in Table 4.1.2.1.A, as necessary.
Complete the following exercise, then discuss the answers with your group.

1. With reference to the terminology of Sentence 4.1.2.1.(1), indicate the classification of structural load that corresponds to each of the following effects:

   a) Ponded rain water on a flat roof

   ☐ D ☐ E ☐ H ☐ L

   ☐ P ☐ S ☐ T ☐ W

   b) Drywall *partitions* in an office *building*

   ☐ D ☐ E ☐ H ☐ L

   ☐ P ☐ S ☐ T ☐ W

   c) Self-weight of a crane rail in an industrial *building*

   ☐ D ☐ E ☐ H ☐ L

   ☐ P ☐ S ☐ T ☐ W

   d) Seismic ground motion causing bending of concrete columns

   ☐ D ☐ E ☐ H ☐ L

   ☐ P ☐ S ☐ T ☐ W

   e) Hydrostatic forces, due to *groundwater*, on a *basement* wall

   ☐ D ☐ E ☐ H ☐ L

   ☐ P ☐ S ☐ T ☐ W

   f) Weight of filing cabinets in an office *building*

   ☐ D ☐ E ☐ H ☐ L

   ☐ P ☐ S ☐ T ☐ W

g) The widening of a parking garage expansion joint in the winter months

☐ D ☐ E ☐ H ☐ L
☐ P ☐ S ☐ T ☐ W

h) Wind uplift between steel roof deck and the supporting open web steel joists

☐ D ☐ E ☐ H ☐ L
☐ P ☐ S ☐ T ☐ W

i) The weight of moist soil and trees on the roof slab of an underground garage

☐ D ☐ E ☐ H ☐ L
☐ P ☐ S ☐ T ☐ W

2. If a load or effect cannot be classified according to Sentence 4.1.2.1(1), which of the following must be done:
   a) the load should be treated as a *live load* "L", with an additional companion load factor
   b) account for it according to the best available information
   c) the load should be treated as a *live load* "L"
   d) the load may be ignored, if approved by a *professional engineer*, since OBC does not require that it be considered.

OBC Reference(s): ________________

STOP

3.4 IMPORTANCE CATEGORIES FOR BUILDINGS

Sentence 4.1.2.1.(3) requires that each *building* be assigned an Importance Category.
The application of these categories to the determination of specified snow, wind, and earthquake loading will be discussed in Modules 5, 6 and 7. The application of these categories to *live loads* due to use and *occupancy* will be discussed in Module 4.

Exercise #3-3

Read Sentence 4.1.2.1(3), Table 4.1.2.1B and Clause 4.1.3.1.(1)(h).
Complete the following exercise, then discuss the answers with your group.

1. For each of the following *building* descriptions, determine the Importance Category in accordance with the OBC:
   a) Single-storey industrial *building*, in a high seismic-risk area, but not containing toxic, explosive or hazardous substances and not low occupant load

      ☐ Low ☐ Normal
      ☐ High ☐ *Post-disaster*

   b) A *farm building*, used for storage of hay, with a maximum occupant load of one person per 50 m^2 of floor area during normal use

      ☐ Low ☐ Normal
      ☐ High ☐ *Post-disaster*

   c) Shopping mall

      ☐ Low ☐ Normal
      ☐ High ☐ *Post-disaster*

   d) School

      ☐ Low ☐ Normal
      ☐ High ☐ *Post-disaster*

   e) Hospital

      ☐ Low ☐ Normal
      ☐ High ☐ *Post-disaster*

   f) Beer Store

      ☐ Low ☐ Normal
      ☐ High ☐ *Post-disaster*

g) Bus terminal

☐ Low ☐ Normal
☐ High ☐ *Post-disaster*

STOP

3.5 LIMIT STATES DESIGN

In simple terms, Limit States are those extreme conditions that would result in a *building* structure not fulfilling the function for which it was designed. The formal definition for Limit States is given in Clause 4.1.3.1.1.(1)(a). Limit states design requires the checking of various conditions at appropriate load levels, to ensure that the structure fulfils the intended functions.

The Code identifies two primary classes of Limit States:

- **Ultimate Limit States (ULS)**: those Limit States concerning safety and stability, which include load-carrying capacity, overturning, sliding and fracture. The Code provisions for these Limit States are given in Article 4.1.3.2, and will be addressed in more detail later in this Module.
- **Serviceability Limit States (SLS)**: those Limit States concerning conditions that restrict the intended use and *occupancy* of a *building*. These include:
    - Deflection, permanent deformation, and local structural damage (such as cracking), as provided for in Article 4.1.3.5.
    - Vibration, as provided for in Article 4.1.3.6.
    - Fatigue due to repeated cycles of load, as provided for in Article 4.1.3.3.

3.5.1 Serviceability Limit States (SLS)

It is important to recognize that when designing for serviceability limit states, the unfactored or "service loads" should be used, as stated in Article 4.1.3.4.

Additional information regarding deflections and vibrations is available in Commentaries D and E of the "User's Guide – National Building Code 2005 Structural Commentaries (Part 4 of Division B)". Note that the content of the User's Guide does not form part of the examination syllabus.

Exercise #3-4

Read Articles 4.1.3.3 to 4.1.3.6, complete the following exercise, then discuss the answers with your group.

1. In the proportioning of a reinforced concrete structural member for deflection, which of the following would not be a consideration?
   a) Limitation of potential damage to finishes as a result of shrinkage cracking
   b) The ultimate strength of the member
   c) Seasonal temperature variations
   d) Long-term creep deflections under sustained loading

   OBC Reference(s): ____________________

2. According to Article 4.1.3.5, what is the maximum allowable *storey* drift **(see Figure 3:1)** of a two-*storey* steel-framed industrial *building* under service wind load?
   a) 1/180th of the *storey* height.
   b) 1/360th of the *storey* height.
   c) 1/500th of the *storey* height.
   d) none of the above, as long as *building* can safely tolerate the movement.

   OBC Reference(s): ________________

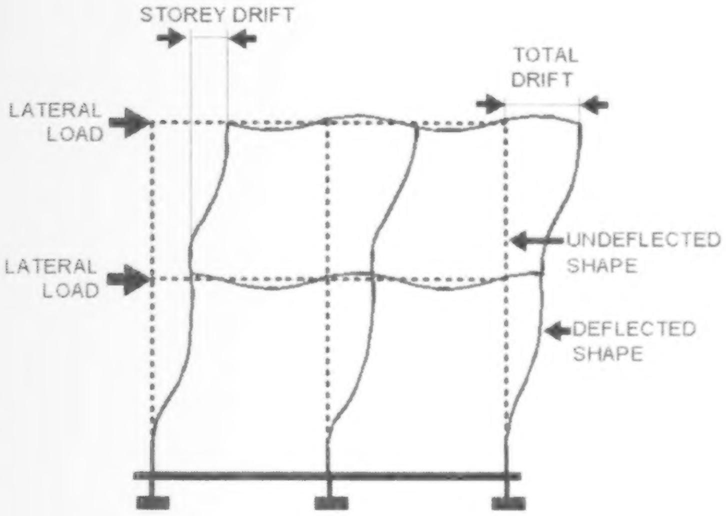
STOREY DRIFT
TOTAL DRIFT
LATERAL LOAD
LATERAL LOAD
UNDEFLECTED SHAPE
DEFLECTED SHAPE

Figure 3:1
Storey Drift of a Building Under Lateral Loading

3. Consider a *building* containing a gymnasium. In undertaking the structural design of the floor in the aerobics training area, which of the following statements is false?
   a) The floor supports an *assembly occupancy*.
   b) The possible effects of resonance need not be considered if the natural frequency of the floor exceeds 6 Hz.
   c) The floor must be designed so that vibrations from the aerobics do not affect the intended *occupancy* of the remainder of the *building*.
   d) In lieu of dynamic analysis for resonance, additional safety factors can be applied.

   OBC Reference(s): ________________

4. In the design of a wood-framed floor system using Part 4, which of the following provide the serviceability criteria to be used?
   a) Article 4.1.3.5.
   b) Article 4.1.3.6
   c) CAN/CSA-O86-01, including supplement CAN/CSA-O86S1-05
   d) All of a), b) and c)

   OBC Reference(s): ______________

5. Which of the following effects may require a dynamic analysis to assess fatigue due to cyclic loading?
   a) Earthquakes
   b) Machinery
   c) Wind
   d) *Live load* due to use and *occupancy*

   OBC Reference(s): ______________

6. Consider a *building* with an effective width of 60 meters, and a height of 180 meters.
   According to Sentence 4.1.3.6.(3), would it be necessary to account for the dynamic effects of wind in the structural design of the *building*?
   a) No, since height/width < 3
   b) Yes, since height/width <4
   c) No, since height >120 m, but height/width <4
   d) Yes, since height >120 m or height/width >4

   OBC Reference(s): ______________

STOP

3.5.2 Ultimate Limit States (ULS) Strength And Stability

In the design of structural members for strength and stability, the philosophy of limit states design is to ensure that the maximum strength of a material exceeds the load that will be imposed upon it, with a reasonable margin of safety against failure. In limit states design, loads and material resistance are treated as probabilities.

In this method, adequacy of strength is addressed by the Code in requiring that " load factors" be used to account for the possibility that actual loads may exceed those anticipated at the time of design. The "factored resistance" (ϕR) of a member is determined by applying a factor (ϕ) less than one, to the nominal member strength (R), to account for variability of material properties, dimensions and workmanship. To ensure adequacy of strength, the factored loads must be less than the factored resistance. This requirement is stated in Sentence 4.1.3.2.(1).

Stability is the ability of a structure to carry load without collapse or excessive deformation. Stability is affected by the manner in which loads are transmitted to structural members, the properties of the member, and the means by which the structure or member is braced to prevent unintended movement. An example of bracing to ensure stability of structural members is given in Figure 3:2.

Sentence 4.1.3.2.(9) addresses Code requirements for structural stability. Additional provisions for structural stability are contained within the various design standards referenced by Section 4.3.

Additional information regarding limit states design is available in Commentary A of the "User's Guide – National Building Code 2005 Structural Commentaries (Part 4 of Division B)." Note that the content of the User's Guide does not form part of the examination syllabus.

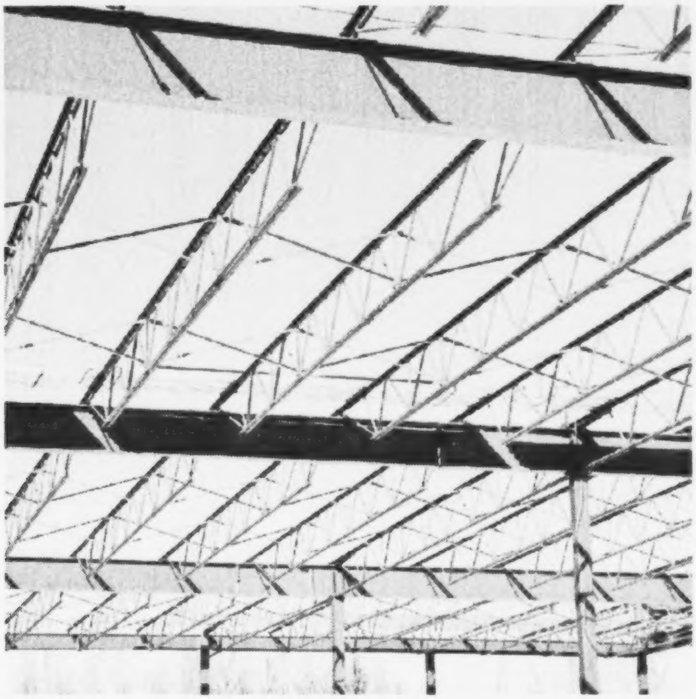

Figure 3:2
Cross-Bridging Of Open Web Steel Joists To Provide Stability
(Photo Credit: The Canam Manac Group Inc.)

3.5.3 Principal and Companion Load Factors

In Article 4.1.3.2 of the Code, the possibility that more than one type of load may act at the same time is considered in the determination of the load factors to be applied to the "service loads".

In any combination of loading, the individual loads are separated into two groups:

- **Principal Loads**: sustained or permanent loads, or loads that are "dominant" in a particular combination of loading
- **Companion Loads**: the transient or variable components of a particular loading combination, that acts for a short time, or rarely

In Table 4.1.3.2, loads are assigned either "principal-load factors" or "companion-load factors", depending on the types of loads acting. The values of these factors account for the probabilities that a number of loads from different sources may act at the same time. In this Table, the factors to be applied to principal loads are generally larger than those applied to companion loads.

Sentence 4.1.3.2.(2) requires that all the load combination cases identified in Table 4.1.3.2 must be evaluated. The case that produces the most critical effect is the case that must be used for Ultimate Limit States design.

In addition to the load factors given in Table 4.1.3.2, the various Sentences forming part of Article 4.1.3.2 include additional provisions where the applicable load factors may require modification. Attention must be given to the notes to Table 4.1.3.2 when using the Code.

Exercise #3-5

Read Articles 4.1.3.1 and 4.1.3.2.
Answer the following questions, then discuss the answers with your group.

1. Which of the following is not permissible under the Code?
    - a) Factored resistance of a member is greater than the factored load on a member
    - b) Factored resistance of a member equals the factored load on a member
    - c) Factored resistance of a member is less than the factored load on a member
    - d) None of the above

   OBC Reference(s): ____________________

2. A column has a *dead load* of 100 kN and a *live load* of 40 kN. What is the critical factored design load?

   a) 140 kN

   b) 145 kN

   c) 185 kN

   d) 280 kN

   OBC Reference(s): ____________________

3. A structural roof member has the following specified loads acting upon it:

   - D = 15 kN/m
   - S = 30 kN/m
   - W = -40 kN/m (i.e., uplift force, acting in an opposite direction to the D and S forces)

   What is the maximum factored uplift load on the member?

   a) 22.3 kN

   b) 27.5 kN

   c) 42.5 kN

   d) 43.8 kN

   OBC Reference(s): ____________________

4. Which of the following statements is false?
   a) For Ultimate Limit States, the principal-load factor for *dead load*, D, must be reduced to 0.9 in cases where the dead load acts to counteract forces that would lead to stress reversal
   b) For storage areas, the principal-load factor for *live load*, L, due to use and *occupancy* may be taken as 1.25
   c) The principal-load factor to be applied to the *dead load*, D, corresponding with 1.4 meters of soil overburden on the roof slab of an underground garage is 1.43
   d) The prestress force, P, in a tie-back anchor used to support a shored soil excavation shall have a load factor of 1.0

   OBC Reference(s): ____________________________

5. What is the load factor to be applied to the specified wind load, when checking serviceability limit states?
   a) 0.40
   b) 1.00
   c) 1.25
   d) 1.40

   OBC Reference(s): ____________________

6. For limit states design, what is the principal-load factor to be applied to *live loads*, L, used when considering the effects of earthquakes?
   a) 0.50
   b) 1.00
   c) 1.50
   d) Not applicable – *live loads*, L, are companion loads when considering earthquakes

   OBC Reference(s): ____________________________

7. With reference to Sentence 4.1.3.1.(1), which of the following is not an "effect" to be considered in Limit States Design?
   a) Moments
   b) Forces
   c) Method of Construction
   d) Deformations

   OBC Reference(s): ____________________

8. A retaining wall has a specified lateral earth pressure overturning moment of 20 kN m /m about the toe, and a dead load stabilizing moment of 40 kN m/m about the toe. The wall is to be designed using the limit states design methods of the OBC.
   a) What is the factored overturning moment?

      ____

   b) What is the factored stabilizing moment?

      ____

   c) Is the wall stable?

      ☐ Yes ☐ No

      Why? ____________________

   OBC Reference(s): ____________________

STOP

3.6 WORKING STRESS DESIGN

The basis for working stress design (also known as "allowable stress design" or "elastic stress design") is that the service loads or service load combinations must not exceed the allowable stresses for a member. The allowable stresses are determined by applying a safety factor to the yield stress or strength for the material under consideration.

Although many older *buildings* have been designed using this method, working stress design is no longer used for the design of *building* structures in Canada. All of the design standards referenced by OBC in Section 4.3 for the various structural materials have adopted a limit states design philosophy.

IN THE 2006 BUILDING CODE, STRUCTURAL DESIGN BY WORKING STRESS METHODS IS NOT RECOGNIZED.

3.7 DESIGN REQUIREMENTS FOR STRUCTURAL MATERIALS

Unlike Part 9, which is mostly prescriptive with respect to the structural components to be used in buildings,
Part 4 generally makes use of reference standards to address design requirements for structural *building* systems and components. The applicable reference standard is dependent on the structural material being considered.

The design and material provisions are given in Section 4.3. Where a reference document or standard is to be used, only the version named in Column 2 of Table 1.3.1.2 (in Division B) are applicable for use with the Code, as qualified by Sentence 1.3.1.1.(2).

It is not within the scope of the Building Structural syllabus nor this course to discuss the content of the structural reference standards. However Code users must be able to recognize which Standards are applicable to particular materials, and which versions of those Standards are to be used.

A23.3-04

Design of concrete structures

CANADIAN STANDARDS ASSOCIATION

Figure 3:3
Standard for Reinforced and Prestressed Concrete Design
(Reference: Sentence 4.3.3.1.(1) and Article 1.3.1.2)

Exercise #3-6

Read Subsections 4.3.1 to 4.3.6.
Complete the following exercise, then discuss the answers with your group.

1. Which of the following reference documents provides the acceptable basis for the design of structural masonry for *buildings* that comply with the 2006 Building Code?
   a) CAN3-S304-M84
   b) CAN/CSA-S304.1-94
   c) CSA-S304.1-04
   d) CSA-A371-04

   OBC Reference(s): ________________

2. For wood structures designed under Part 4, built in areas known to be infested with termites, which of the following is not a true statement?
   a) untreated wood shall not be placed within 450 mm of the ground
   b) hollow masonry *foundation* walls supporting floor joists shall be capped with solid masonry or concrete
   c) wood debris shall be removed to a depth of 200 mm in unexcavated areas below the *building*
   d) wood framing shall be designed in accordance with CAN/CSA-O86.

   OBC Reference(s): ________________

3. If a member is being designed under the provisions of CSA Standard S157, what is the structural material under consideration?
   a) Glass
   b) Glue-Laminated Wood
   c) Cold-Formed Steel
   d) Aluminum

   OBC Reference(s): ________________

4. If a design is being undertaken using a structural material that is not referenced in Section 4.3, what is the acceptable design basis for that material?
   a) The ASTM standard corresponding to that material
   b) Generally-established theory, provided the design is by an especially qualified person
   c) Any method approved by the *Chief Building Official*
   d) The Code does not allow use of materials that are not listed in Section 4.3

   OBC Reference(s): ________________

STOP End of Module 3

MODULE 4

DEAD LOADS AND LIVE LOADS DUE TO OCCUPANCY

TABLE OF CONTENTS

4.0 Introduction 1
4.1 Objectives 1
4.2 Structural Loads 1
4.3 Dead Loads 2
4.4 Live Loads Due to Use and Occupancy 8

4.0 INTRODUCTION

In this Module, we will learn the Code requirements for determining *dead loads* and *live loads* due to use and *occupancy* in *buildings*, using Part 4.

4.1 OBJECTIVES

Upon completion of this Module, participants will be able to:

- Describe the differences between *dead loads* and *live loads*
- Calculate and verify *dead loads* for sample building assemblies, and know where to find information to determine *dead loads*
- Determine uniform and concentrated *live loads* due to use and *occupancy*
- Apply the concept of tributary area, and apply the applicable Code provisions for tributary areas in determining *live loads*
- Relate the implications and importance of full and partial *live loading* on *buildings*

4.2 STRUCTURAL LOADS

The process of the design of a *building* structure is not a simple linear task, and often involves trial-and-error calculation procedures. One of the most important steps in the structural design process is the determination of the design loads to which a *building* is subjected. Without knowledge of the loads, one cannot begin analysis of the internal forces, stress and deformations, and selection of appropriate members.

4.3 DEAD LOADS

Dead loads are the weights of all permanent structural and nonstructural components of a *building,* and are generally sustained loads that do not change over the life of the *building*. The formal definition for *dead load* is given Sentence 4.1.4.1.(1).

Masses and weights of typical construction materials can be found in commonly-used design handbooks such as:

- Handbook of Steel Construction, published by the Canadian Institute of Steel Construction
- Concrete Design Handbook, published by the Cement Association of Canada (formerly the Canadian Portland Cement Association)
- Wood Design Manual, published by the Canadian Wood Council

Figures 4:1 and 4:2, are examples of some typical *dead loads*. Technical literature published by manufacturers also a good source of information on *dead load* for specific construction products. It is considered good design practice to show the design *dead loads* on structural drawings, so that these loads can be verified during the plans examination for a *building* permit, and during any future renovations to a *building*.

MASS AND FORCES FOR MATERIALS

MATERIAL	Mass (kg/m³)	Force (kN/m³)	MATERIAL	Mass (kg/m³)	Force (kN/m³)
METALS, ALLOYS, ORES			TIMBER, AIR-DRY		
Aluminum	2 640	25.9	Birch	689	6.76
Brass	8 550	83.8	Cedar	352	3.45
Bronze, 7.9-14% tin	8 150	79.9	Fir, Douglas, seasoned	545	5.34
Bronze, aluminum	7 700	75.5	Fir, Douglas, unseasoned	641	6.29
Copper	8 910	87.4	Fir, Douglas, wet	801	7.86
Copper ore, pyrites	4 200	41.2	Fir, Douglas, glue laminated	545	5.34
Gold	19 300	189	Hemlock	481	4.72
Iron, cast, pig	7 210	70.7	Larch, tamarack	561	5.50
Iron, wrought	7 770	76.2	Larch, western	609	5.97
Iron, spiegel-eisen	7 500	73.5	Maple	737	7.23
Iron, ferro-silicon	7 000	68.6	Oak, red	689	6.76
Iron ore, hematite	5 210	51.1	Oak, white	753	7.38
Iron ore, hematite in bank	2 560-2 880	25.1-28.2	Pine, jack	481	4.72
Iron ore, hematite, loose	2 080-2 560	20.4-25.1	Pine, ponderosa	513	5.03
Iron ore, limonite	3 800	37.3	Pine, red	449	4.40
Iron ore, magnetite	5 050	49.5	Pine, white	416	4.08
Iron slag	2 760	27.1	Poplar	481	4.72
Lead	11 400	112	Spruce	449	4.40
Lead ore, galena	7 450	73.1	For pressure treated timber add retention to mass of air-dry material.		
Magnesium	1 790	17.6			
Manganese	7 610	74.6			
Manganese ore	4 150	40.7			
Mercury	13 600	133	LIQUIDS		
Monel	8 910	87.4	Alcohol, pure	785	7.70
Nickel	9 050	88.8	Gasoline	673	6.60
Platinum	21 300	209	Oils	929	9.11
Silver	10 500	103			
Steel, rolled	7 850	77.0	Water, fresh at 4°C (max. density)	1 000	9.81
Tin	7 350	72.1	Water, fresh at 100°C	961	9.42
Tin ore, cassiterite	6 700	65.7	Water, salt	1 030	10.1
Zinc	7 050	69.1			
Zinc ore, blende	4 050	39.7	EARTH, ETC. EXCAVATED		
			Earth, wet	1 600	15.7
MASONRY			Earth, dry	1 200	11.8
Ashlar	2 240-2 560	22.0-25.1	Sand and gravel, wet	1 920	18.8
Brick, soft	1 760	17.3	Sand and gravel, dry	1 680	16.5
Brick, common	2 000	19.6			
Brick, pressed	2 240	22.0	VARIOUS BUILDING MATERIALS		
Clay tile, average	961	9.42			
Rubble	2 080-2 480	20.4-24.3	Cement, Portland, loose	1 510	14.8
Concrete, cinder, haydite	1 600-1 760	15.7-17.3	Cement, Portland, set	2 930	28.7
Concrete, slag	2 080	20.4	Lime, gypsum, loose	849-1 030	8.33-10.1
Concrete, stone	2 310	22.7	Mortar, cement-lime, set	1 650	16.2
Concrete, stone, reinforced	2 400	23.5	Quarry stone, piled	1 440-1 760	14.1-17.3
SOLID FUELS			MISCELLANEOUS		
Coal, anthracite, piled	753-929	7.38-9.11	Asphaltum	1 300	12.7
Coal, bituminous, piled	641-865	6.29-8.48	Tar, bituminous	1 200	11.8
Coke, piled	368-513	3.61-5.03	Glass, common	2 500	24.5
Charcoal, piled	160-224	1.57-2.20	Glass, plate or crown	2 580	25.3
Peat, piled	320-416	3.14-4.08	Glass, crystal	2 950	28.9
			Paper	929	9.11
ICE AND SNOW					
Ice	897	8.80			
Snow, dry, fresh fallen	128	1.26			
Snow, dry, packed	192-400	1.88-3.92			
Snow, wet	432-641	4.24-6.29			

Figure 4:1

Typical Masses of Materials For Dead Load Determination (Part 1 of 2)
(from: Handbook of Steel Construction, 9th Edition)

DESIGN DEAD LOADS (kPa) OF MATERIALS

STEEL DECKS	
Steel deck* 38 mm deep	
(up to 0.91 mm thick)	0.10
(1.22 to 1.52 mm thick)	0.15
Steel deck* 76 mm deep (Narrow-Rib)	
(up to 0.91 mm thick)	0.15
(1.22 to 1.91mm thick)	0.30
Steel deck* 76 mm deep (Wide-Rib)	
(up to 0.91 mm thick)	0.10
(1.22 to 1.52 mm thick)	0.15
* for cellular deck, add	0.08
CONCRETE, per 100 mm	
- 2350 kg/m^3 (N.D.)	2.31
- 2000 kg/m^3 (slag aggregate)	1.96
-1850 kg/m^3 (S.L.D.)	1.82
HOLLOW CORE PRECAST (no topping)	
- 200 mm deep (N.D.)	2.60
- 300 mm deep (N.D.)	3.50
WOOD JOISTS (at 400 mm centres)	
- 38 mm x 184 mm joists	0.09
- 38 mm x 235 mm joists	0.12
- 38 mm x 286 mm joists	0.14
PLYWOOD	
- 11 mm thick	0.06
- 14 mm thick	0.08
- 19 mm thick	0.11
CHIPBOARD	
- 12.7 mm thick	0.07
- 15.9 mm thick	0.09
- 19.0 mm thick	0.11
WALLS AND CLADDING	
- Solid brick wall (concrete)	
- 100 mm thick (S.L.D.)	1.40
- 100 mm thick (N.D.)	1.90
- Hollow block (S.L.D.)	
- 100 mm thick	1.10
- 200 mm thick	1.60
- 300 mm thick	2.30
- Hollow block (N.D.)	
- 100 mm thick	1.40
- 200 mm thick	2.10
- 300 mm thick	2.90
- P.C. wall plus glazing	2.40 - 3.80
- Metal curtain wall	0.74 - 1.50
- Insulated sheet steel wall (exclude girts)	0.25 - 0.40
- 38 x 89 wood studs @ 400 mm	0.05
- Gypsum wallboard per 10 mm	0.08
- Stone veneer per 25 mm	0.40

FLOOR FINISHING	
- Vinyl, linoleum or asphalt tile	0.07
- Softwood subfloor per 10 mm	0.06
- Hardwood per 10 mm	0.08
- Carpeting	0.10
- Asphaltic concrete per 10 mm	0.23
- 20 mm Ceramic or quarry tiles on 12 mm mortar bed	0.80
- Terrazzo per 10 mm	0.24
- Mastic floor (20 mm)	0.45
ROOFING	
- 3 ply asphalt, no gravel	0.15
- 4 ply asphalt, no gravel	0.20
- 3 ply asphalt and gravel	0.27
- 4 ply asphalt and gravel	0.32
- Asphalt strip shingles	0.15
- Gypsum wallboard per 10 mm	0.08
INSULATION (per 100 mm thick)	
- Glass fibre, batts	0.05
- Glass fibre, blown	0.04
- Glass fibre, rigid	0.07
- Urethane, rigid foam	0.03
- Insulating concrete	0.06
CEILINGS	
- Gypsum wallboard per 10 mm	0.08
- Tiled ceiling & suspension system, with fixtures, average	0.20
- 20 mm plaster on lath/furring	0.40
- Sprayed fire protection, average	0.07
- Ducts/pipes/wiring allowance (average condition)	0.25
DECK-SLABS (average condition)	
- 38 mm deck with	
- 65 mm N.D. cover*	1.95
- 90 mm N.D. cover*	2.55
- 65 mm S.L.D. cover**	1.55
- 85 mm S.L.D. cover**	1.90
- 75 mm (or 76 mm) "wide-rib" deck with	
- 65 mm N.D. cover*	2.55
- 90 mm N.D. cover*	3.15
- 65 mm S.L.D. cover**	2.15
- 85 mm S.L.D. cover**	2.50
- 76 mm "narrow-rib" deck with	
- 65 mm N.D. cover*	2.20
- 90 mm N.D. cover*	2.80
- 65 mm S.L.D. cover**	1.90
- 85 mm S.L.D. cover**	2.25
* assume 2350 kg/m^3 concrete	
** assume 1850 kg/m^3 concrete	

Note: 1 kN/m^2 = 1 kPa

Figure 4:2

Typical Masses of Materials For Dead Load Determination (Part 2 of 2)
(from: Handbook of Steel Construction, 9th Edition)

In general, the self-weight of the structural members is the largest component of the *dead load* of a *building,* however, this will depend largely on the actual materials chosen. Concrete-framed *buildings* would have a larger proportion of *dead loads* due to self-weight as compared to wood or steel-framed *buildings*.

It is important in structural design to develop reasonably accurate estimates of the *dead loads* on *buildings* for the following reasons:

- *Dead loads* tend to represent that largest proportion of total load on structural members such as slabs, beams, columns and *foundations*, therefore over-estimates of *dead load* can lead to overdesign and unnecessary construction cost.
- As will be seen in Module 7, the determination of earthquake loads will depend largely on the *dead load* of a *building*.
- *Dead load* may be relied upon to resist overturning forces (see Module 3 and Sentence 4.1.3.2(4)), therefore over-estimating *dead load* may not necessarily be conservative.
- Long term deformations due to "creep effects" depend on the sustained *dead load*, therefore accurate estimates of *dead load* are required for serviceability design checks.

Those persons familiar with the application of Part 9 of OBC will recognize that the determination of *dead loads* is not generally done for Part 9 *buildings*. In the development of the prescriptive requirements and the tables for member selection in Part 9, there are inherent assumptions regarding the characteristic *dead loads* of houses and small buildings, based on "typical construction". However, Subsection 9.4.1 outlines the circumstances where the design of Part 9 buildings must be done using the provisions of Part 4. In such cases, *dead loads* would need to be determined using the requirements of Part 4.

Example #4-1:

For the roof assembly shown in Figure 4:3, determine the design *dead load* for the open web steel joists.
Assume that the unit weight of rigid insulation is 0.40 kN/m^3 and the self-weight of the joists is 0.50 kN/m.
(Note: 1 kN/m^2 = 1 kPa)

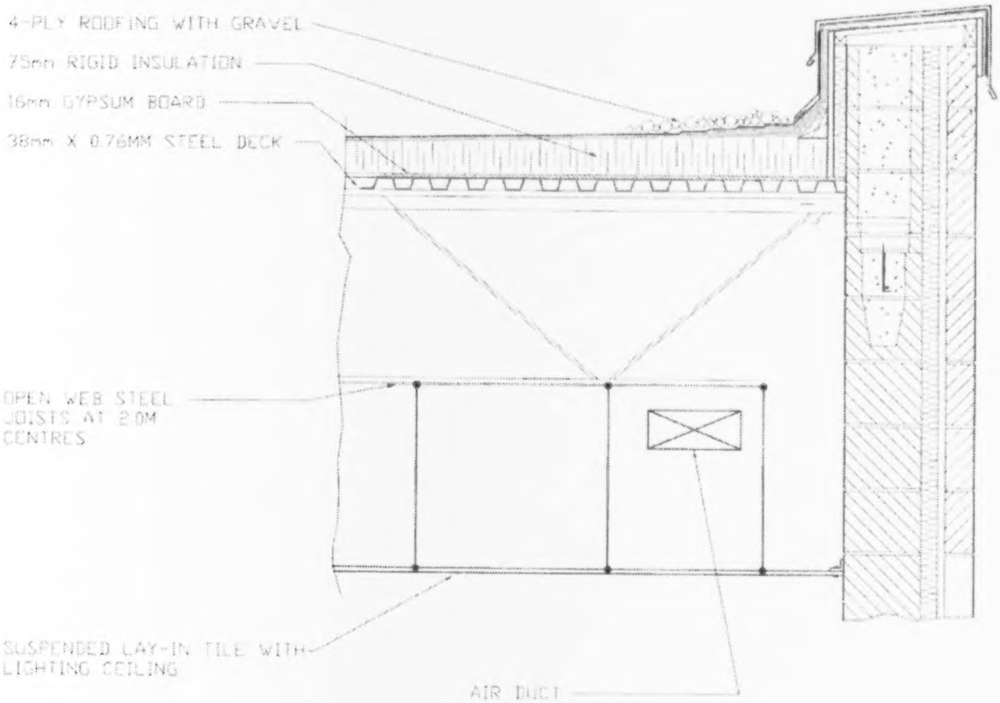
4-PLY ROOFING WITH GRAVEL
75mm RIGID INSULATION
16mm GYPSUM BOARD
38mm X 0.76MM STEEL DECK
OPEN WEB STEEL JOISTS AT 2.0M CENTRES
SUSPENDED LAY-IN TILE WITH LIGHTING CEILING
AIR DUCT

Figure 4:3

Roof Assembly Cross-Section (for Example #4-1)

Solution:

Roofing system		0.32 kPa	(from Fig 4:2)
Rigid insulation	0.40 kN/m^3 * 0.075 m =	0.03 kPa	
Gypsum board	0.08 kPa * 16 mm/10 mm =	0.13 kPa	(From Fig 4:2)
Steel deck		0.10 kPa	
TOTAL DEAD LOAD ON DECK		**0.58 kPa**	**(kN/m^2)**

Roofing and Decking	0.58 kPa * 2.0 m =	1.16 kN/m	
Joist self-weight		0.50 kN/m	
Ducts/pipes/wiring	0.25 kPa * 2.0m =	0.50 kN/m	(from Fig 4:2)
Ceiling system	0.20 kPa * 2.0m =	0.40 kN/m	(from Fig 4:2)
TOTAL JOIST DEAD LOAD		**2.56 kN/m**	**(kN per meter run)**

Exercise #4-1

Read Subsection 4.1.4 and Sentence 4.1.5.2.(1). Complete the following exercise, then discuss the answers with your group.

1. Which of the following are not considered by the Building Code to be *dead loads*?

    a) Permanent *partitions* in an office *building*
    b) Future *partitions* that are likely to be added to an office *building*
    c) Furnishings and stored materials located in a storage room
    d) Weight of trees on a "green roof"

    OBC Reference(s): ________________

2. In a *building* with non-loadbearing drywall *partitions* having an average self-weight of
0.5 kPa, what minimum *partition dead load* should be used for the design of the floor slabs?

    a) 0 kPa
    b) 0.5 kPa
    c) 1.0 kPa
    d) 0.5 kPa plus a 1.0 kPa allowance for future partitions.

    OBC Reference(s): ________________

3. For the *building* in question 2 above, what is the *partition dead load* that should be used in assessing the overturning resistance of the *building* to wind loads?

    a) 0 kPa
    b) 0.5 kPa
    c) 1.0 kPa
    d) None of the above

    OBC Reference(s): ________________

4. Consider a cantilever retaining wall in which the weight of *soil* above the footing is relied upon to provide stability against possible overturning. Considering the requirements of Sentence 4.1.4.1.(6), what load factor must be applied to the vertical *dead load* due to *soil* when designing to counteract the effects of overturning?

   a) 0.0, since *soil* weight must be neglected
   b) 0.9 or 1.0, as required by Sentence 4.1.3.2.(4)
   c) 1.25, or as otherwise required by Sentence 4.1.3.2.(7)
   d) 1.40 as required by Table 4.1.3.2

   OBC Reference(s): ______________

STOP

4.4 LIVE LOADS DUE TO USE AND OCCUPANCY

According to Division A, Article 1.4.1.2:

> *"Live load means a variable load due to the intended use and occupancy that is to be assumed in the design of the structural members of a building and includes loads due to cranes and the pressure of liquids in containers."*

Live loads are not permanent and can change in magnitude during the life of a *building*. The magnitudes of *live loads* are difficult to determine with the same degree of accuracy that is possible with *dead loads*, which is the reason for the corresponding higher *live load* factors in Article 4.1.3.2.

The probable maximum values of live loads due to use and occupancy have been determined over time by research and experience, and are prescribed by the Building Code in Subsection 4.1.5. The required design live load depends on the type of occupancy for a building, or portion of a building. In general, live loads for assembly occupancies are more restrictive, given the great significance of structural failure of such portions of buildings. The definition of assembly occupancy, given in Division A, Article 1.4.1.2 should be kept in mind when applying the provisions of Subsection 4.1.5.

The *live loads* due to *occupancy* required by the Code are given as a minimum design *live load* per unit area, but also include requirements for concentrated loadings.

Code requirements in Subsection 4.1.5 include additional provisions for special applications, such as bleacher seating, helicopter landing areas, multiple *occupancies*, exterior areas and roof parking decks.

If the *major occupancy* of a *building* changes after the time of construction, then the design of the renovations will require re-assessment of the *live loads* and the structure's ability to carry them. More discussion on the structural aspects of renovations, covered by Part 11, will be given in Module 19. However, it should be recognized that Article 4.1.5.6 allows a loading reduction for dining areas where areas in *buildings* are converted from another *occupancy*.

Subsection 4.1.5 also includes provisions for the *live loads* on *buildings* and designated structures, other than those live loads that act on floors and roofs. These *live loads*, which include crane-supporting structures, guards and walls, will be discussed in Module 8.

It should be recognized that the prescriptive design provisions in OBC Part 9 have limitations based on *live load*. For example, OBC 9.23.4.1(1)(b) limits the selection of floor joists, beam and lintels in Part 9 *buildings* to those occupancies with *live load* corresponding to *residential occupancies*, or 1.9 kPa. Thus, even in Part 9 buildings, it is an important step in the application of the Code to determine the *live load* due to use and *occupancy* using Part 4.

Exercise #4-2

Read Articles 4.1.5.1 to 4.1.5.11, 4.1.5.13 and 4.1.5.14. Complete the following exercise, then discuss the answers with your group.

1. With reference to Table 4.1.5.3, what is the minimum uniformly distributed *live* load due to *occupancy*, for the following *occupancies*?

a) Shopping mall ____ kPa

b) *Exits* ____ kPa

c) Exercise room in an apartment *building* ____ kPa

d) First *storey* offices ____ kPa

e) Library _____ kPa

f) Unoccupied roof, not used for helicopter landings _____ kPa

g) Roof, used as restaurant patio bar, but not subject to the allowance of Article 4.1.5.6 _____ kPa

h) 1225 mm wide corridor on the 3rd floor of a residential apartment *building*, that cannot be used for assembly _____ kPa

Notes:

____

____

i) Bedrooms of an apartment *building* designed using Part 3. _____ kPa

j) Corridor of a nursing home with 50 residents _____ kPa

2. With respect to *live load* due to *occupancy*, which of the following statements is incorrect?

   a) The specified live load depends on the intended use and occupancy.
   b) Specified uniformly distributed loads and specified concentrated loads shall be considered in combination.
   c) Live loads for *occupancies* not listed in Table 4.1.5.3 shall be determined on the basis of probable loads.
   d) An area of floor intended for two *occupancies* at different times shall be designed for the larger of the *live loads* corresponding to the two *occupancies*.

   OBC Reference(s): _______________

3. When is it permissible to reduce the specified *live loads* shown in Table 4.1.5.3 by 20%?

a) When the load is already factored
b) When the *building* is in the Low Importance Category
c) When the design is for a renovation under Part 11 and the *performance level* is not reduced
d) Never

OBC Reference(s): ________________

4. What is the specified *live load* for the lower level of apartment *building* parking garage accessible to passenger cars only?

a) 2.4 kPa
b) 4.8 kPa
c) 2.4 kPa, or a concentrated load of 11 kN
d) 4.8 kPa, or a concentrated load of 18 kN

OBC Reference(s): ________________

5. According to Table 4.1.5.10, what is the minimum concentrated *live load* to be used in the design of the floors for sleeping areas of residential *buildings*?

a) 1.3 kN
b) 4.5 kN
c) 9.0 kN
d) none of the above

OBC Reference(s): ________________

6. In a hockey arena, which of the following are not a specified horizontal *live load* case to be considered in the design of a floor supporting fixed spectator seating?

a) 0.3 kN/m, for each row of seats, in a direction parallel to the seating rows
b) 0.15 kN/m, for each row of seats, in a direction perpendicular to the seating rows
c) 1.75 kN/m for each linear meter of seating, or a concentrated load of 2.2 kN applied over a length of 750 mm, at any location
d) There are no applicable Code requirements

OBC Reference(s): ________________

7. A roof joist has been determined to have the following specified loads:

   - *Dead Load* (D) = 1.9 kN/m
   - Minimum *occupancy live load* (L) = 1.8 kPa,
   - Maximum effect of snow and rain loading (S) = 2.5 kN/m, from Sentence 4.1.6.1.(1)

   Using Sentence 4.1.5.5.(2) and Table 4.1.3.2, and neglecting wind and earthquake loading, what is the maximum factored load on the joist?

   a) 3.75 kN/m
   b) 6.13 kN/m
   c) 6.33 kN/m
   d) 7.03 kN/m

   OBC Reference(s): ________________

8. Which of the following is an untrue statement?

   a) The paved areas of a concrete roof slab of an underground parking garage, accessible to vehicles weighing more than 9000 kg, must be designed for a minimum concentrated load of 54 kN, but not less than the expected weight of fire fighting trucks.
   b) Telescoping bleacher seating must have locking devices, and all bleachers shall be checked after erection.
   c) The requirements for roofs intended for use as helicopter landing areas are given in the Canadian Aviation Regulations.
   d) If the average weight of equipment in a mechanical room is 5.1 kPa, but Table 4.1.5.3 shows the specified uniform *live load* for a *service room* to be 3.6 kPa, then it is permitted to design the floor for a specified design *live load* of 3.6 kPa.

   OBC Reference(s): ________________

STOP

4.4.1 Variation of Live Load with Tributary Area

It is not likely that full design loads will occur on every portion of a *building* at the same time. Therefore, the Code allows for the reduction of the design *live load* on structural elements supporting large tributary areas, such as girders, columns or foundations.

In the case of a member that supports a load directly, such as a beam or slab, tributary area is defined as the area supported by that member. In the case of structural members that indirectly support loads, such as columns or foundations, the total area from all parts of the *building* that apply load to that member must be considered in calculating the tributary area.

Additional information regarding the determination of tributary areas and *live load* reductions is available in Commentary F of the "User's Guide – National Building Code 2005 Structural Commentaries (Part 4 of Division B)". Note that the content of the User's Guide does not form part of the examination syllabus.

Exercise #4-3

Read Article 4.1.5.9.
Complete the following exercise, then discuss the answers with your group.

1. A reinforced concrete shearwall in an apartment *building* supports a tributary area of 180 m^2 of residential living area. If no other *occupancies* are tributary to the wall, what is reduction factor that may be applied to the *live load* on the shearwall?
   a) 0
   b) 0.53
   c) 0.83
   d) 1.00

OBC Reference(s): ________________

2. A girder supports a tributary floor area of 100 m^2 of storage *occupancy*. What is the total minimum specified *live load* on the girder due to use and occupancy?

   a) 95 kN

   b) 294 kN

   c) 456 kN

   d) 480 kN

OBC Reference(s): ______________

3. For a movie theatre, what is the *live load* reduction factor that may be applied to the 2.4 kPa *live load* on a column supporting a tributary area of 100 m^2?

   a) 0.00

   b) 0.61

   c) 0.95

   d) No *live load* reduction allowed

   OBC Reference(s): ______________

4. When applying the *live load* reduction factors of Article 4.1.5.9, which of the following is true?

   a) Reduction factors are not allowed for *assembly occupancies*.

   b) The reduction factors to *live load* may be applied to the loads determined under Article 4.1.5.10

   c) The structural drawings must show that a reduction factor was used in the design.

   d) The 1.0 kPa minimum *live load* for roofs may be reduced using the equation in Sentence 4.1.5.9.(3)

   OBC Reference(s): ______________

STOP

4.4.2 Full and Partial Loading

Article 4.1.5.3 of the Code requires that the specified uniformly distributed *live load* be applied uniformly over the entire area, or on any portions of the area, so as to produce the most critical effect in the structural members concerned. These effects are not limited to strength only, as the design for serviceability may also be affected by "patterning" of *live load*.

It is not necessarily true that full load on all portions of a structure will produce the most critical effects for all parts of the structure. The analysis of structures for pattern loading is beyond the scope of this course.

STOP End of Module 4

MODULE 5

SNOW AND RAIN LIVE LOADS

BUILDING STRUCTURAL – 2006

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5.0 INTRODUCTION

In this Module, we will learn how to determine the minimum snow live loads required by the Building Code for the design of *building* structures, and introduce the differences in the methods of determining snow loads for Part 4 and Part 9 *buildings*. We will also discuss why rain loads and snow loads must be considered separately.

5.1 OBJECTIVES

Upon completion of this Module participants will be able to:

- Explain the differences between snow loads in Part 9 *buildings* and *buildings* designed using Part 4
- Apply the climatic data tables from Supplementary Standard SB-1, in determining snow loads
- Identify the factors affecting snow loads
- Recognize the differences between associated rain, S_r and specified rain load
- Calculate the specific snow and rain loads for specific locations for *buildings* using Part 4, with given factors

5.2 MINIMUM ROOF DESIGN LOADS

As discussed in Module 4, the minimum *live loads* on roofs are given in Sentences 4.1.5.1.(1) and 4.1.5.10.(1) and Tables 4.1.5.3 and 4.1.5.10. The corresponding Part 9 requirements may be found in Sentence 9.4.2.2.(3).

Where a roof of a *building* may be used for *occupancy*, then the designer must also ensure that the minimum *occupancy live loading* requirements are satisfied. Examples of where a roof may be used for occupancy purposes include rooftop terraces, garden or patios, the uppermost levels of elevated parking garages, or the landscaped roofs of underground parking garages.

It should be recognized that the provisions of Article 4.1.5.9 for reduction of *live load* based on tributary area do *not* apply to the snow and rain *live loads,* or to the minimum *live load* on roofs.

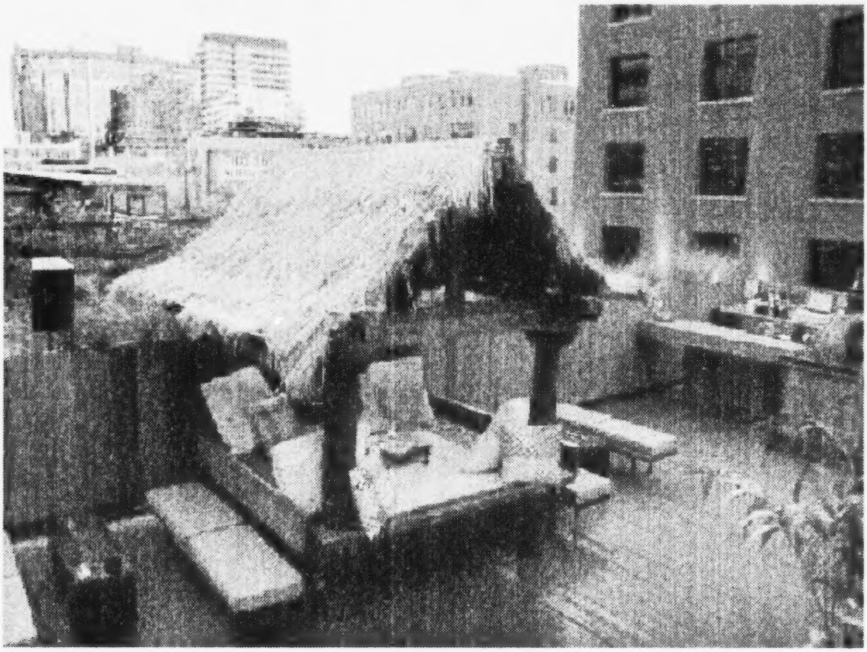

Figure 5:1
Roof Occupancy Loading

5.3 SPECIFIED SNOW LOADS ON BUILDINGS USING PART 4

Snow and rain loads on roofs vary according to geographical location, site exposure, shape and type of the roof. To account for these variations, the Building Code prescribes a required snow loading, to be used in the design of *buildings*, based on probability, research and experience.

The specified snow load, S, on a roof is determined by multiplying the ground snow load for a *building's* location by a series of coefficient factors, as given in Sentence 4.1.6.2(1):

$$S = I_s [S_s (C_b C_w C_s C_a) + S_r)]$$

where:

I_s = importance factor for snow load,
S_s = 1-in-50-year ground snow load,
C_b = basic roof snow load factor,
C_w = wind exposure factor,
C_s = slope factor,
C_a = shape factor, and
S_r = 1-in-50-year associated rain load

These coefficient factors reflect the effects of exposure of the *building* to wind, the effect of roof slope, and the effect of drifting, sliding, creep and drainage. The uses of these multiple factors allow the designer to separately assess the effects of each factor affecting the snow load.

Note that in Sentence 4.1.6.2.(1), the Code sets an upper limit on S_r as the lesser of:

- value in Table 1.2 of SB-1, and
- $S_s (C_b C_w C_s C_a)$

In other words, the upper limit on the specified load, S, due to snow and associated rain is set at:

$$S = 2 * I_s [S_s (C_b C_w C_s C_a)]$$

The Code does not allow a reduction in the design snow load where a *building* has maintenance provisions for the clearing of snow, or the use of snow-melting systems. However, in cases where snow-clearing operations may result in large accumulations of snow, such as on the roofs of parking garages, consideration must be given to the possibility of the weight of large accumulations of snow, as well as to the *live loads* due to equipment used to clear the snow.

Additional information regarding snow loads is available in Commentary G of the "User's Guide – National Building Code 2005 Structural Commentaries (Part 4 of Division B)".
Note that the content of the User's Guide does not form part of the examination syllabus.

5.3.1 Ground Snow Load (S_s) and Associated Rain Load (S_r)

To use the formula in Sentence 4.1.6.2.(1), it is necessary to establish the snow and "associated rain" coefficients for a building's location:

$$S = I_s\,[\mathbf{S_s}\,(C_b\,C_w\,C_s\,C_a) + \mathbf{S_r}]$$

The values of ground snow load, S_s, for various locations in Ontario are given in column 12 of Table 1.2 of Supplementary Standard SB-1. This value is normally 0.4 for Southern Ontario.

To account for the fact that rain may occur after snow, design snow loads must include an allowance for the rain. This effect is accounted for in the Code by use of associated rain load, S_r, the values of which are given in column 13 of Table 1.2 of Supplementary Standard SB-1.

In Table 1.2, the term "1-in-50" refers to the probability that the estimated load will be exceeded once in 50 years.

Note that there is an upper limit on the value of S_r, as stated in Sentence 4.1.6.2.(1).

Exercise #5-1

Read Sentence 4.1.6.2.(1) and Supplementary Standard SB-1. Complete the following exercise, then discuss the answers with your group.

1. What is the 1-in-50 year ground snow load and associated rain load to be used for a *building* in Ottawa?
   a) S_s = 2.4 kPa and S_r = 0.4 kPa
   b) S_s = 2.4 kPa and 0.23 kPa (23 mm) of rain
   c) S_s = 2.4 kPa and 0.84 kPa (86 mm) of rain
   d) S_s = 2.4 kPa and 7.4 kPa (750 mm) of rain

   OBC Reference(s): ______________________

2. What five majors factors affect the specified snow load for a roof?
   a) ________________________________
   b) ________________________________
   c) ________________________________
   d) ________________________________
   e) ________________________________

   OBC Reference(s): ______________________

STOP

5.3.2 Importance Factor for Snow, I_s

With reference to Sentence 4.1.6.2.(1), the importance factor for snow load must be evaluated for each building, for use in the following expression:

$$S = \mathbf{I_s} [S_s (C_b C_w C_s C_a) + S_r]$$

As discussed in Module 3, all *buildings* are assigned an Importance Category according to Sentence 4.1.2.1.(3), based on use and *occupancy*. From this category, an importance factor for snow loading, I_s, must be determined using Table 4.1.6.2.

Different importance factors must be used when designing for ultimate limit states (ULS) and serviceability limit states (SLS) for earthquake, snow and wind.

Exercise #5-2

Read Table 4.1.6.2. Review the categories of limit states discussed in Module 3, as necessary. Complete the following exercise, then discuss the answers with your group.

1. What is the value of I_s to be used when designing a roof beam in a hospital for strength and stability?

   a) 0.9

   b) 1.0

   c) 1.15

   d) 1.25

   OBC Reference(s): ____________________

2. What is the value of I_s to be used in determining the snow load for a shopping mall to check deflections of structural framing?

   a) 0.8

   b) 0.9

   c) 1.0

   d) 1.2

   OBC Reference(s): ____________________

STOP

5.3.3 Wind Exposure Factor, C_w

When a roof is not shielded from the wind by any significant obstructions, the amount of snow on the roof tends to be reduced by the erosion action of the wind. The obstructions affecting wind shielding may be either on the roof, or adjacent to the *building*.

The amount of snow load reduction allowed by the Code depends on the degree to which the roof is exposed. Sentences 4.1.6.2.(3) and 4.1.6.2.(4) state the Code provisions for the wind exposure factor, C_w, to be applied in accordance with Sentence 4.1.6.2.(1):

$$S = I_s [S_s (C_b \mathbf{C_w} C_s C_a) + S_r]$$

Most designers tend to take the value of $C_w = 1.0$ unless there is some certainty that the roof will not become shielded in the future. The specific conditions that allow the use of an exposure factor of less than 1.0 are given in Sentence 4.1.6.2.(4), and should be reviewed by the reader.

In Clause 4.1.6.2.(4)(b), reference is made to the unit weight of snow. Information on the unit weight of snow is available in Commentary G of the "User's Guide – National Building Code 2005 Structural Commentaries (Part 4 of Division B)".

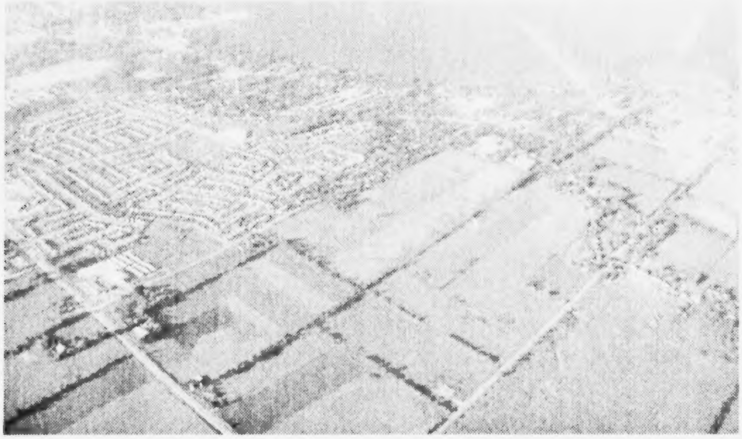

Figure 5:2
Rough Terrain (Left) and Open Terrain (Right) – See Sentence 4.1.6.2.(4)

Exercise #5-3

Read Sentences 4.1.6.2.(3) and 4.1.6.2.(4).
Complete the following exercise, then discuss the answers with your group.

1. Which of the following statements is false?

   a) For the purpose of determining C_w, open-terrain is considered "level terrain with only scattered buildings, trees or other obstructions, open water or shorelines".

   b) C_w of 0.5 may be used in exposed open-terrain areas north of the treeline, if there are significant obstructions on the roof

   c) For *buildings* with a "high" importance category in accordance with Table 4.1.2.1.B, the wind exposure factor, C_w, is always 1.0

   d) For *post-disaster buildings*, the wind exposure factor, C_w, is always 1.0

   OBC Reference(s): ______________________

2. A *building* in Richmond Hill has a flat roof, exposed to wind on all four sides. The terrain is open, and is expected to remain so over the life of the *building*. There is a 1.0 m high parapet at the edges of the roof. What is the minimum value of C_w that can be used to determine the snow load on the roof at a point located 5 m from the parapet?
Assume the unit weight of snow is 3.0 kN/m^3, and C_b = 0.8.
(Hint: Assume an appropriate value for C_w, then use the equation in the Code to check your assumption)
   a) $C_W = 0.50$
   b) $C_W = 0.75$
   c) $C_W = 1.00$
   d) $C_W = 1.25$
   OBC Reference(s): ____________________

STOP

5.3.4 Basic Roof Snow Load, C_b

The Building Code recognizes that the average snow load on a roof is generally less than it would be on the ground. This is mainly due to the effects of wind and melting (due to thermal losses) in removing snow from roofs. Accordingly, a factor of less than 1.0 can be applied to the ground snow load, as described in Sentences 4.1.6.1.(1) and 4.1.6.2.(2):

$$S = I_s\,[S_s\,(\mathbf{C_b}\,C_w\,C_s\,C_a) + S_r]$$

However, for large flat roofs, wind tends to be less effective in removing snow, due to the larger overall quantities of snow as compared to smaller buildings, and due to retarded airflow or "aerodynamic shading".

Recognizing this, Sentence 4.1.6.2.(2) accounts for the effects of roof size, through the basic roof snow load factor, C_b. The roof size is described by a characteristic length, L_c, which is based only on roof width, length and the wind exposure of the roof.

Exercise #5-4

Read Sentence 4.1.6.2.(2) and 4.1.6.2.(4).
Complete the following exercise, then discuss the answers with your group.

1. The roof of a building has a length of 75 m and a width of 40 m. What is the characteristic length of the roof?

   a) $L_c = 40.0$ m

   b) $L_c = 58.7$ m

   c) $L_c = 75.0$ m

   d) Lc = 128.0 m

   OBC Reference(s): ____________________

2. The roof of a *building* has a characteristic length of 68.5 m and is in an urban area (not considered to be open terrain).
   What is the minimum value of C_b that must be used to determine snow loading?

   a) $C_b = 0.80$

   b) $C_b = 0.81$

   c) $C_b = 0.82$

   d) $C_b = 2.88$

   OBC Reference(s): ____________________

3. If the *building* in question 2 has a characteristic length of 125 m, what minimum value of C_b should be used to determine snow loading?

   a) $C_b = 0.76$

   b) $C_b = 0.80$

   c) $C_b = 0.94$

   d) $C_b = 1.00$

   OBC Reference(s): ____________________

STOP

5.3.5 Slope Factor, C_s

For sloped roofs, the Code allows a reduction to the "flat roof snow load", to account for the probability that some snow will slide off the roof:

$$S = I_s [S_s (C_b C_w \mathbf{C_s} C_a) + S_r]$$

The amount of the reduction is applied through the use of the slope factor, C_s, as given by Sentences 4.1.6.2.(5) to 4.1.6.2.(7).

Factors affecting the ability of snow to slide include the slope of the roof, and how "slippery" the roof surface is.

For slippery surfaces described in Sentence 4.1.6.2(6), a lower value of C_s may be used than for non-slippery surfaces. Slippery surfaces include:

- Metal
- Slate
- Glass
- Smooth rubber or plastic without embedded aggregates or mineral grains

Non-slippery surfaces include:

- Plastics or rubbers with an embedded aggregate or mineral grains
- Asphalt shingles
- Wood shingles
- Wood shakes
- Tiles

Reduction of snow load on a sloped roof due to sliding effects is limited by the Code to those roofs when the roof's surface is completely unobstructed, with no objects existing on it that may prevent the snow from sliding completely off the roof. An example of where sliding of snow may be prevented is shown in Figure 5:3.

Caution should be used when selecting values of C_s, to determine the snow load on sloped roofs, to make sure that the sliding can actually occur.

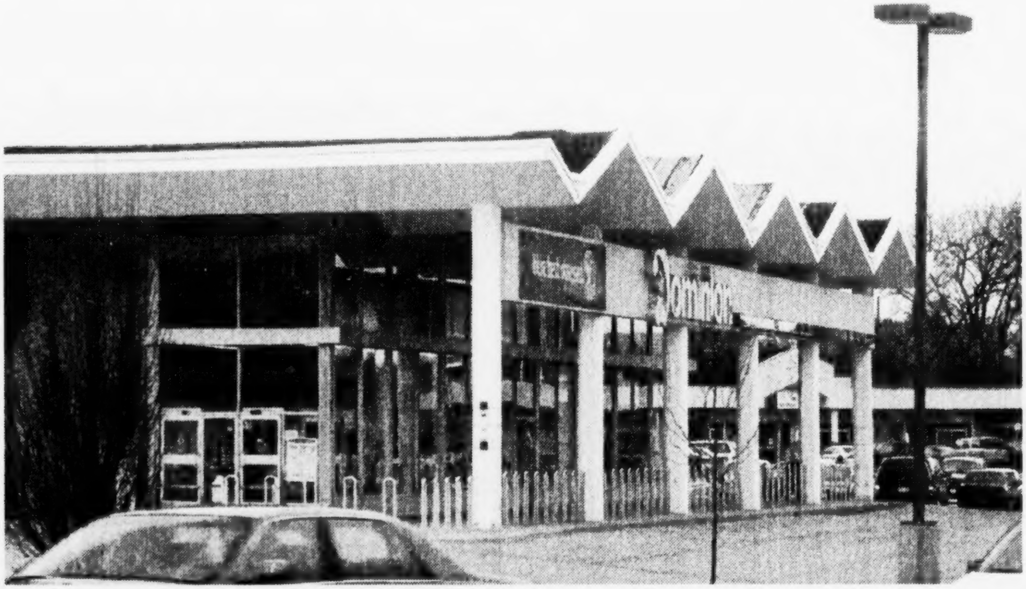

Figure 5:3

Sloped Roof Where "Snow Sliding" May Be Prevented

(Photo Credit: Tusia Designs)

Exercise #5-5

Read Sentences 4.1.6.2.(5) to 4.1.6.2.(7).
Complete the following exercise, then discuss the answers with your group.

1. For sloped roofs in which the sliding of snow is unobstructed, which of the following statements is not true?
   a) For a roof with asphalt shingles and a slope of 40°, $C_s = 0.75$
   b) For a roof slope of 60°, $C_s = 0$ if the roof is slippery
   c) For a roof slope of 30°, $C_s = 1.0$ if the roof is not slippery
   d) For glass skylight with a slope of 45°, $C_s = 0.63$

   OBC Reference(s): ____________________

2. Consider the roof shown in Figure 5:3. The angle of slope is 35°, and the roof surface is slippery. If a "shape factor" of 1.5 has been assigned to the valleys of the roof using Clause 4.1.6.2.(8), what is the slope factor, C_s, which should be used to determine snow loading?

   a) $C_s = 0.33$

   b) $C_s = 0.63$

   c) $C_s = 1.00$

   d) $C_s = 1.50$

   OBC Reference(s): ____________________

STOP

5.3.6 Shape Factor, C_a

It is extremely important to consider localized snow drifts in the design of roofs. Drifts accumulate on roofs due to accumulation of snow:

- On lower roof of multi-level roofs, or at penthouses,
- On roofs adjacent to nearby higher *buildings*,
- Adjacent to roof obstructions such as skylights, solar panels, parapets and roof-mounted mechanical equipment.
- Due to sliding effects (e.g. roof valleys, and domes and curved/arched roofs.)

Sentence 4.1.6.2(8) describes the situations where one must consider snow accumulation, by applying a shape factor, C_a, for use with Sentence 4.1.6.2(1):

$$S = I_s [S_s (C_b C_w C_s \mathbf{C_a}) + S_r]$$

Information on the determination of the shape factor, C_a, is available in Commentary G of the "User's Guide – National Building Code 2005 Structural Commentaries (Part 4 of Division B)". Note that the content of the User's Guide does not form part of the examination syllabus.

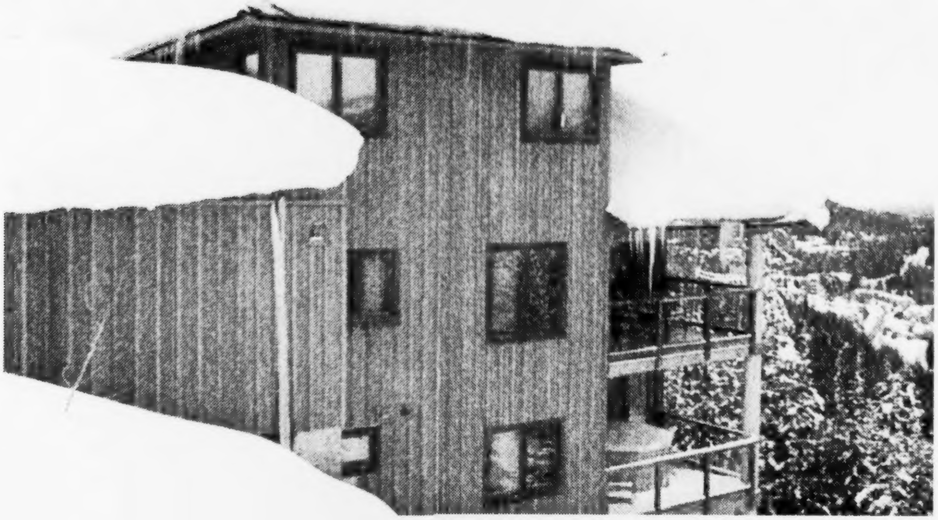

Figure 5:4
"High-Low" Roof Condition – see Clause 4.1.6.2.(8)(b)

Exercise #5-6

Read Sentence 4.1.6.2.(8).

Complete the following exercise, then discuss the answers with your group.

1. According to Sentence 4.1.6.2.(8), which of the following would not be considered as causing potential roof snow drifts:
   a) masonry chimneys
   b) concrete parapets
   c) characteristic length of roof
   d) mechanical penthouse

   OBC Reference(s): ____________________

2. It is proposed to construct a 15-*storey building* immediately adjacent to a 6-*storey building* on the same property. If the storey heights of both *buildings* are the same, what clear horizontal distance would be required between the *buildings* to ensure that an increase in snow loading does not occur on the existing roof?

   a) Distance must be equal to the difference in *building heights*

   b) New *building* can be set adjacent to property line

   c) *Buildings* must be separated by 5.0 metres

   d) Existing *building* must be demolished

   OBC Reference(s): ______________________

Exercise #5-7

Using all the provisions of Article 4.1.6.2, answer the following questions, then discuss the answers with your group.

1. A "high importance" *building* in Belleville has a flat roof and a characteristic length of 30 metres.
   If the *building* is not exposed to wind, what is the specified load, S, due to snow and associated rain, that must be used for Ultimate Limit States (ULS) design of the roof?

   a) 1.76 kPa

   b) 1.93 kPa

   c) 1.96 kPa

   d) 2.02 kPa

   OBC Reference(s): ______________________

2. If the *building* in question 1 were located in Windsor, what specified load, S, would you use to design the roof for Serviceability Limit States (SLS)?

   a) 0.94 kPa

   b) 1.00 kPa

   c) 1.04 kPa

   d) 1.20 kPa

   OBC Reference(s): ____________________

STOP

5.4 FULL AND PARTIAL LOADING

Uneven distribution of snow loads may create an imbalance effect on certain types of structural members that may be more critical to the design than a heavier mass of uniform snow.

For this reason, Article 4.1.6.3 requires that members be designed for the full snow load, as well as for the case where the full load is on one portion of a member, and 50% of the load on the remainder of the member.

It is the responsibility of the structural designer to determine how the loads must be patterned, considering the behaviour of the structure, in such a way as to produce the greatest effects on the member concerned. It should be noted that in most cases, roofs will require consideration of several load pattern cases to ensure proper design of all structural members. The structural engineering principles associated with load patterns are beyond the scope of this course.

Exercise #5-8

Read Article 4.1.6.3. Complete the following exercise, then discuss the answers with your group.

1. Which type of structural system would not require consideration of full and pattern loading or snow?

   a) cantilevered beams supporting a flat roof

   b) arched roof with rise/span < 0.1

   c) arched roof with rise/span > 0.1

   d) none of the above

   OBC Reference(s): ____________________

2. In applying full and partial loading to the lower roof shown in Figure 5:4, what shape factor, C_a, should be used to calculate the snow load?

   a) 0

   b) 0.60 if above the treeline

   c) $(60 - \alpha)/45$

   d) 1.0

   OBC Reference(s): ____________________

3. In the structural design of a roof framing system, which of the following would not be a loading scenario that is required by the Code?

   a) Full snow loading and partial snow loading, using the SLS factors from Table 4.1.6.2

   b) Full snow loading and partial snow loading, using the ULS factors from Table 4.1.6.2

   c) Full and partial loading, where the roof load in Table 4.1.5.3 exceeds the loads determined under the provisions of Article 4.1.6.2.

   d) Full snow loading and partial snow loading using the shape factors required by Article 4.1.6.2.(8)

   OBC Reference(s): ____________________

STOP

5.5 SPECIFIED RAIN LOADS

Roofs must be designed for the weight of probable rain, in accordance with the requirements of Article 4.1.6.4.

It is a common misconception that the "associated rain load", S_r, in the calculation of snow loads accounts for the effects of rain. The Code requires that a separate load calculation be done, to account for the possible weight of rainwater that may accumulate on a roof in one day. The design rainfall is given in Supplementary Standard SB-1, and varies according to geographical location.

Considering that water tends to accumulate at low points, the depth of water at low points on roofs may exceed the depth corresponding to the 24-hour rain, and effects of rain loading may be more critical to the structure than the snow load. It is necessary that the designer determine whether the snow or rain loading is critical, at each location on a roof.

Special consideration should be given to roofs designed for the purpose of storm water retention using "control flow roof drains", as has become common practice in several municipalities. In such situations, roof drains with controlled flow rates are used to limit the rates of water discharge into the sewer system, and it is possible that depths of water larger than those occurring in a 24-hour period may occur. Article 4.1.6.4 requirements for the 24-hour rainfall do not necessarily address the issue of storm water retention, and the requirements of Subsection 4.1.5 with respect to "intended use" would govern such designs.

In determining the design depth of rainwater at any location on a roof, the designer must account for the undeformed shape of the roof, as well as the deflection of the roof under the weight of rainwater. As water accumulates at low areas, a portion of a roof may deflect more, allowing a deeper pond to form at that location, which can eventually lead to structural failures. This phenomenon is known as "ponding instability", and is discussed in detail in Commentary H of the "User's Guide – National Building Code 2005 Structural Commentaries (Part 4 of Division B)".

Figure 5:5

Rain Load, S, on a Roof – see Article 4.1.6.4

Exercise #5-9

Read Article 4.1.6.4. Complete the following exercise, then discuss your answers with your group.

1. For a flat roof in Sudbury, what is the amount of rainwater that must be accounted for when applying the provisions of Article 4.1.6.4?

   a) 25mm/day

   b) 97 mm/day

   c) 650 mm/week

   d) Unit weight of water divided by S_r = 0.4 kPa

   OBC Reference(s): ____________________

2. For the roof in question 1, consider that the roof is sloped such that the roof is 200 mm lower at the drains than at the parapets. How would the design depth of rainwater at the low points compare with your answer to question 1?

   a) More than question 1
   b) Less than question 1
   c) The same as question 1
   d) The provisions of Article 4.1.6.4 do not apply

   OBC Reference(s): ______________________

3. A flat roof in Leamington has $C_b=0.8$, $C_w=1.0$, $C_w = 1.0$, $C_a=1.0$ and $I_s=1.0$. Neglecting slopes to drains and secondary ponding effects, which of the following is the specified load, S, for the ULS design of the roof? (Hint: assume water density = 9.8 kN/m^3)

   a) 1.00 kPa
   b) 1.04 kPa
   c) 1.11 kPa
   d) 1.68 kPa

   OBC Reference(s): ______________________

4. If the roof in question 3 were located in Cambridge, which of the following is the specified load, S, for the ULS design of the roof?

   a) 1.11 kPa
   b) 1.20 kPa
   c) 1.51 kPa
   d) 1.68 kPa

   OBC Reference(s): ______________________

STOP End of Module 5

MODULE 6

WIND LOADS

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6.0 INTRODUCTION

In this Module, we will learn how to determine the minimum wind loads required by the Building Code for the design of *building* structures. This Module covers the Code provisions for determining wind loads on a *building* as a whole, as well as for individual structural components and cladding.

6.1 OBJECTIVES

Upon completion of this Module participants will be able to:

- Explain the factors affecting wind load determination using the Building Code
- Elaborate on the differences between internal and external pressure
- Find reference velocity pressures for various locations in Ontario
- Determine which method of wind load determination is applicable to a particular *building*
- Verify calculations for determining wind loads, using the static method.
- Identify the applicable wind loads patterns required by the Code

6.2 WIND LOADS

Lateral loads are those *live loads* whose main component is to apply a horizontal force to a *building*. Lateral loads include:

- wind loads (W)
- earthquakes (E)
- earth pressure, such as on retaining walls or basement/*foundation* walls (H)

In order to simplify design and analysis, the Building Code models the dynamic effects of wind and earthquake loads as equivalent static (non-variable) loads in most small and moderate-sized *buildings*.

More complex *buildings* may require the use of "dynamic analysis" in which the response of the *building* to lateral loads has an effect on the nature of the loads; these methods generally require the use of computer models, and are beyond the scope of this course.

The most common lateral loads are wind loads. The CN Tower or telecommunications towers are examples of structures where wind loads are the most significant design load.

In general, wind acting on a *building* exerts a positive pressure on the windward side and a negative pressure (or suction) on the leeward side. Depending on the shape of the *building*, wind may also cause uplift pressure (suction) to act on roof, and negative pressure (suction) on the side walls. In addition, the effects of openings in the *building* envelope can result in the positive or negative pressurization of the *building* interior, which results in additional pressure on the walls and roof. The pressure on exterior walls and roof is not uniform, but varies across the surface, according to height and building shape.

Despite the wind being predominantly from the west in Ontario, the Code requires that wind from all directions be considered in the design of *buildings*.

Wind loads must be accounted for in the design of:

- **Main Lateral Load Resisting System**: an assemblage of structural components to provide support and stability for the overall *building*. Examples include shearwalls, diaphragms, cross-bracing, k-bracing, moment-resisting frames, foundations.
- **Components and Cladding**: elements of the building envelope that do not qualify as part of the main lateral load resisting system. Examples include brick ties, roof purlins and wall sheathing. Components and cladding may be part of the main lateral load resisting system when acting as a shearwall or diaphragm; for example, an exterior masonry load bearing wall may be subject to both in-plane (shearwall loads), and out-of-plane (cladding) wind loads.

6.3 METHODS FOR DETERMINING WIND LOADS ON BUILDINGS

Under the provisions of the Building Code, a *building* designed using Part 4 will require determination of the specified wind load using one of three methods:

- Static Procedure,
- Dynamic Procedure, or
- Experimental Procedure.

The Static Procedure is appropriate for most low- and medium-rise buildings. In this method, the specified wind forces are determined based on the geometry of the building, the geographic location, and a series of coefficients. Buildings designed using the static procedure are generally rigid, therefore the wind load does not depend on the response of the building structure to the dynamic effects of wind.

The Dynamic Procedure for wind load determination is appropriate for tall and slender buildings (but not necessarily for cladding and secondary structural members). In this method, the effects of wind turbulence and the properties of the building (such as the natural frequency of vibration and damping) are considered.

The Experimental Procedure involves wind-tunnel tests or experimental methods, and can be used as an alternate to either the Static or Dynamic Procedures. The experimental procedure more accurately anticipates loads and often will result in elements being designed for lower loads than either the state or dynamic methods.

Article 4.1.7.2 states the Code circumstances when the dynamic or experimental procedures are required, or in other words, the circumstances when the static procedure may not be used. To apply Article 4.1.7.2, it is first necessary to determine the "effective width, w" of a *building*, which is given by the following expression:

$$w = \frac{\Sigma\, h_i w_i}{\Sigma\, h_i}$$

where,

h_i = the height above *grade* to "level I", for the surface (exposed to wind) being considered

w_i = the width normal (at 90 degrees) to the wind direction, at height h_i

The Code does not state the detailed requirements for the dynamic or experimental procedures for wind load determination. These requirements are given in Commentary I of the "User's Guide – National Building Code 2005 Structural Commentaries (Part 4 of Division B)".
Note that the content of the User's Guide does not form part of the examination syllabus.

The Code does not disallow the use of dynamic or experimental procedures for any building, but it does disallow the static method to be used for the building types outlined in Article 4.1.7.2.

Exercise #6-1

Read Article 4.1.7.2. Complete the following exercise, then discuss your answers with the group.

1. Which of the following properties of a *building* would not require the use of experimental methods or dynamic analysis to determine wind loads?
   a) Low natural frequency for the main lateral load resisting system
   b) Height to effective width ratio less than or equal to 4
   c) Low damping properties of the *building*
   d) Lightweight construction

   OBC Reference(s): ______________________

2. Consider a two-storey *building*.
The lowest storey has a height of 4 metres and a width of 40 metres. The upper storey has a height of 4 metres and a width of 30 metres.
If the reference height, h_i, is the elevation above ground at mid-height of each storey, what is the effective width of the *building*?

   a) 32.5 m

   b) 33.3 m

   c) 35.0 m

   d) 40.0 m

   OBC Reference(s): ____________________

d)

3. For which of the following *buildings* is the determination of the specified wind loads using the static procedure allowed?

   a) Effective Width = 80 m, Height = 80 m but building is lightweight with a low natural frequency

   b) Effective Width = 80 m, Height = 15 m, and not susceptible to wind vibrations

   c) Width = 15 m, Height = 80 m, but building is normal weight construction and is well-damped

   d) Effective width = 100 m, Height = 130 m

   OBC Reference(s): ____________________

STOP

6.4 DETERMINATIONS OF EQUIVALENT STATIC EXTERNAL WIND PRESSURE, p

Factors affecting the external wind pressures on a building wind load include:

- the geographic location, elevation, and degree of exposure,
- relationship to nearby structures,
- *building* height and size,
- direction of winds,
- velocity of winds,
- positive or negative pressures due to the shape of the *building*, and
- other architectural features that may affect wind behaviour.

These factors are taken into account by the Building Code by the use of various coefficients, which when multiplied, result in a design wind pressure. Article 4.1.6.2 identifies the coefficient factors to be used in determining static wind pressure:

$$p = I_w q\, C_e C_g C_p$$

where,

p = the specified external pressure acting statically and in a direction normal to the surface, either as a pressure directed towards the surface or as a suction directed away from the surface

I_w = importance factor for wind load

q = the reference velocity pressure

C_e = the exposure factor

C_g = the gust effect factor, and

C_p = the external pressure coefficient averaged over the area of the surface considered.

External wind pressures and pressures acting from the interior of the *building* are considered separately. Internal wind pressures will be discussed in a later part of this Module.

6.4.1 Importance Factor for Wind, I_w

As discussed in Module 3, all *buildings* are assigned an Importance Category according to Sentence 4.1.2.1.(3), based on use and *occupancy*. From this category, an importance factor for wind loading, I_w, must be determined using Table 4.1.7.1, and applied when using Sentence 4.1.7.1.(1):

$$p = I_w q\, C_e C_g C_p$$

Different importance factors must be used when designing for ultimate limit states (ULS) and serviceability limit states (SLS).

Exercise #6-2

With reference to Table 4.1.7.1, complete the following exercise, and then discuss your answers with the group.

1. What is the value of I_w to be used when designing the exterior cladding for strength in a minor storage *building*?

   a) 0.75

   b) 0.80

   c) 1.00

   d) 1.25

   OBC Reference(s): ____________________

2. What is the value of I_w to be used in determining the wind load for a shopping mall to check the overall deflections of the main lateral force resisting system?

   a) 0.75

   b) 0.80

   c) 1.00

   d) 1.25

   OBC Reference(s): ____________________

STOP

6.4.2 Reference Wind Velocity Pressure, q

The basic design wind load in the Code is the velocity pressure of a wind lasting for a few seconds that will be exceeded, on the average, once in 50 years.

Column 15 of Table 2-1 in Supplementary Standard SB-1 provides reference wind pressures, q, for various geographical locations. These values of q are to be used with the equation in Sentence 4.1.7.1.(1):

$$p = I_w \mathbf{q} C_e C_g C_p$$

Exercise #6-3

With reference to Supplementary Standard SB-1, complete the following exercise, then discuss your answers with the group.

1. For a *post-disaster building* in Kingston, what is the reference velocity pressure, q?
   - a) 0.35 kPa
   - b) 0.40 kPa
   - c) 0.47 kPa
   - d) 0.59 kPa

   OBC Reference(s): ____________________

2. For an office *building* in Oshawa, what is the reference velocity pressure, q?
   - a) 0.40 kPa
   - b) 0.43 kPa
   - c) 0.57 kPa
   - d) not of the above

   OBC Reference(s): ____________________

STOP

6.4.3 Exposure Factor, C_e

The roughness of the earth's surface tends to disturb uniform wind flow. Since turbulence is initiated at ground level, ground wind speeds and pressures tend to be much less than those at higher elevations.

The Code addresses this behaviour by the use of an exposure factor, C_e, that increases with the height of the *building* component under consideration:

$$p = I_w q \mathbf{C_e} C_g C_p$$

Sentence 4.1.7.1(5) describes how to determine C_e. When determining the exposure factor, the Code requires that consideration be given to the characteristics of the terrain surrounding the *building*, which affects the wind speed profile due to turbulence.

Examples of open and rough terrain are given in Figure 6:1. The variation of C_e with height and the type of terrain is illustrated in Figure 6:2.

The equations of Sentence 4.1.7.1(5) are not applicable to wind loads determined by dynamic analysis.

Further information on the relationship between terrain and exposure factor is available in Commentary I of the "User's Guide – National Building Code 2005 Structural Commentaries (Part 4 of Division B)".

In Sentence 4.1.7.1(5), it is important to know the "reference height" for the portion of the building for which the exposure factor is being determined. Guidance on the selection of the reference height is in the aforementioned User Guide.

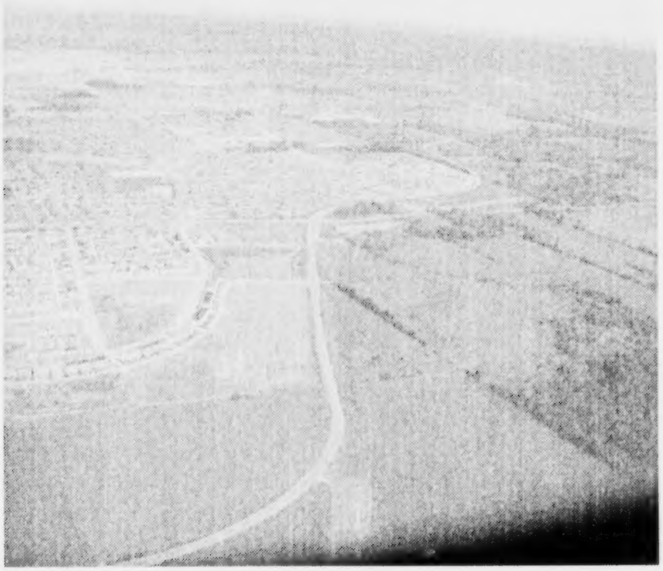

Figure 6:1
Rough Terrain (Left) and Open Terrain (Right) – Sentence 4.1.7.1.(5)

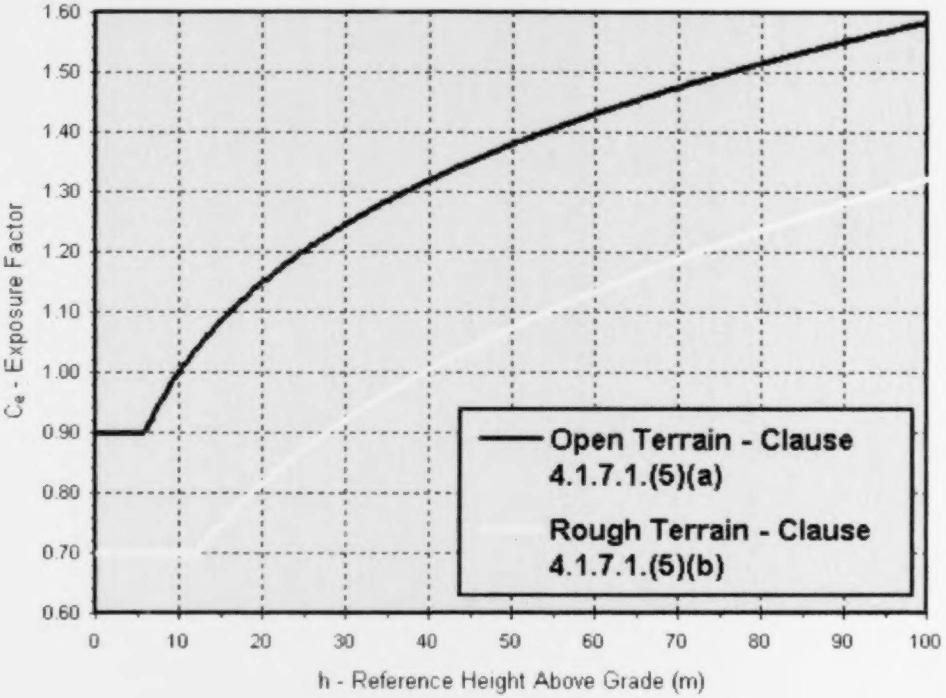

Figure 6:2

Variation Of Exposure Factor C_e With Reference Height

Exercise #6-4

With reference to Sentence 4.1.7.1(5), complete the following exercise then discuss your answers with the group.

1. Consider an apartment *building* in an urban area, with roof height 60 m.
   What is the value of C_e to be used for the design of the roof for wind effects?

   a) 1.00

   b) 1.13

   c) 1.43

   d) 1.62

   OBC Reference(s): ____________________

2. For the *building* in question 1, what would the value of C_e be for roof design, if the effective width of the *building* perpendicular to the direction of wind were 14 m?

   a) 1.36

   b) 1.48

   c) 1.50

   d) None of the above

   OBC Reference(s): ____________________

3. Which of the following statements is true?

   a) The type of terrain for determining the exposure factor can be found in Supplementary Standard SB-1

   b) For interior wind pressures, C_e is always 1.0

   c) In order to use $C_e = 0.7(h/12)^{0.3}$, it is necessary that there be no open terrain within 1 km (or 10 times the height of the *building*, whichever more) of the *building*

   d) When the terrain is neither "open" nor "rough", the Code requires the designer to use the equations of Clauses 4.1.7.1.(5)(a) and 4.1.7.1.(5)(b), and select the value of C_e that is greater

   OBC Reference(s): ____________________

STOP

6.4.4 Gust Factor, C_g

Wind pressures on *buildings* are extremely variable, and are affected by:

- Random wind gusts that may act on parts of buildings or on whole *buildings*
- Fluctuations in wind flow due to redirection of wind around a *building*
- Fluctuations in force caused by the motion of the *building* under wind loading.

In the determination of equivalent static wind load by Article 4.1.7.1(1), the Code addresses gusting by assigning an appropriate factor to the reference velocity pressure:

$$p = I_w q C_e \mathbf{C_g} C_p$$

The gust factor, C_g, is the ratio of the maximum expected wind gust pressure to the average wind gust pressure, and is given in Article 4.1.7.1(6).

Exercise #6-5

With reference to Article 4.1.7.1(6), complete the following exercise then discuss the answers with your group.

1. Which of the following statements is false?
   a) For determining the exterior wind pressure on non-loadbearing exterior precast concrete wall panels, $C_g = 2.5$.
   b) For internal wind pressures in a *building*, $C_g = 2.5$ if the pressure is acting on a main structural member.
   c) In the determination of wind by dynamic methods, C_g can not be determined solely by provisions of the Code
   d) In designing the main wind-bracing of a *building* for serviceability limit states, the wind forces should take $C_g = 2.0$

   OBC Reference(s): ______________

2. In the design of brick ties in a masonry veneer wall, what value of C_g should be used for determining the exterior wind pressure on the wall?

   a) 1.00

   b) 2.00

   c) 2.50

   d) none of the above

   OBC Reference(s): ____________________

3. In the design of sloped glazing for the effects of wind, what value of C_g should be used for determining wind pressures on the main structural members in the glazing system?

   a) 2.00

   b) 2.25

   c) 2.50

   d) 3.00

   OBC Reference(s): ____________________

STOP

6.4.5 External Pressure Coefficent, C_p

The pressure distributions on a *building* can be expressed as non-dimensional pressure coefficients, based on the shape of a *building*. Pressure coefficients used in design are based on experimental testing of models of different types and shapes of buildings in wind tunnels.

When using the static method for wind, the external pressure coefficient, C_p, is applied to a *building* using Sentence 4.1.6.2.(1):

$$p = I_w q C_e C_g \mathbf{C_p}$$

The orientation of a building to the wind and the slope of a roof have a significant effect on pressure distribution, particularly on the edges and corners of buildings. A sample distribution of pressure coefficients on a *building* is given in Figure 6:3.

Pressure coefficients for determining static wind loads are found in Commentary I of the "User's Guide – National Building Code 2005 Structural Commentaries (Part 4 of Division B)". The commentary includes pressure coefficients for a wide variety of building shapes.

The values given in Commentary I correspond to the average pressures acting at 90 degrees to a surface. Thus, for sloped surfaces, wind pressures have horizontal and vertical components.

In Commentary I, the convention is that pressures tending to "push inward" on a building are "positive pressures", with a value of C_p greater than zero. As such, wind suction action on the surface of a building is considered to be a "negative pressure", with C_p being less than zero. This convention is illustrated in Figure 6:3.

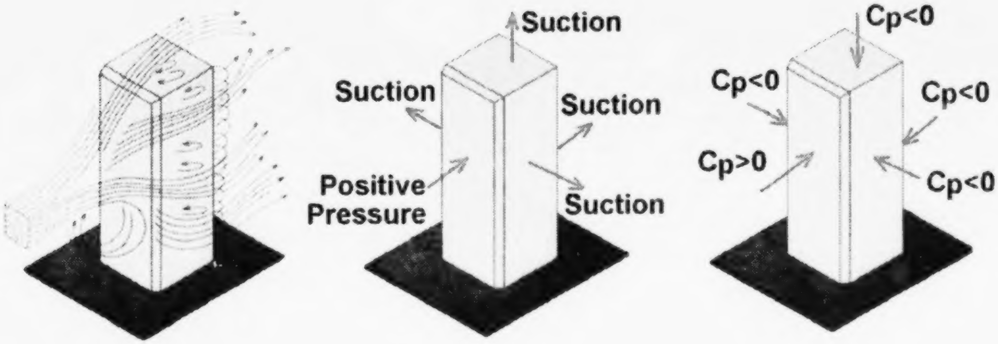

Figure 6:3
Wind Pressure Directions on Buildings
and Sign Convention for External Pressure Coefficients

Exercise #6-6

Read Sentences 4.1.7.1.(1) and (2).
Complete the following exercise then discuss the answers with your group.

1. Which of the following statements is false?

   a) Sentence 4.1.7.1.(1) can be used to determine the specified wind pressure on a *building*, or on any portion of a *building*

   b) When a surface has different values of C_p, the greatest value should be used.

   c) Static external pressure acts at 90 degrees to the surface under consideration

   d) When the external pressure is acting in suction, the specified external wind pressure "p" is less than zero, since suction is a "negative pressure" acting on a surface.

   OBC Reference(s): ____________________

2. A *building* in downtown Brockville has a normal importance category, and the roof is 12 m above ground. The external pressure coefficient, C_p, for the roof is –1.3. What is the specified external static wind pressure on the roof, for ULS design of the main structure?

   a) 0.80 kPa, acting upward

   b) 0.80 kPa acting downward

   c) 1.19 kPa, acting upward

   d) 1.19 kPa acting downward

   OBC Reference(s): ________________

3. Using Article 4.1.7.1.(1) and Commentary I of the "User's Guide – National Building Code 2005 Structural Commentaries (Part 4 of Division B)", the following has been determined:

   - On the windward face of the *building*, the average C_p = 1.00 and p = 0.75 kPa
   - On the leeward face of the *building*, the average C_p = -0.80 and p = -0.60 kPa
   - On the side faces of the *building*, the average C_p = -0.85 and p = -0.63 kPa

   If the area the windward and leeward faces is 200 m^2 each, what is the net specified wind load on the *building*, in the direction parallel to the wind?

   a) –30 kN

   b) 30 kN

   c) 150 kN

   d) 270 kN

   OBC Reference(s): ________________

STOP

6.5 INTERNAL WIND PRESSURE, p_i

All *buildings* have an internal air pressure, that may be either larger or smaller than the outside air pressure. As such, the internal pressure may tend to push the *building* envelope outward or inwards. These internal pressures must be considered as additional to the exterior wind pressures on a *building*.

The specified internal pressure acting on part or all of a surface of a *building* is determined using Sentence 4.1.7.2.(3):

$$p_i = I_w q\, C_e C_{gi} C_{pi}$$

where,

p_i = the specified internal pressure acting statically and in a direction normal to the surface, either as a pressure directed towards the surface or as a suction directed away from the surface
I_w = importance factor for wind load
q = the reference velocity pressure
C_e = the exposure factor
C_{gi} = the internal gust effect factor, and
C_{pi} = the internal pressure coefficient

Article 4.1.7.1.(3) requires that the effects of the net pressure acting on any surface exposed to wind be considered. In other words, the internal pressure and the wind pressure acting on exterior surfaces must be considered acting in combination. Examples of situations where internal and external pressures (acting together) may affect the design of building components elements would include roofs and exterior walls.

In general, the effects of interior pressures need not be considered in the determination of global forces on the *building* as a whole, used for the design of the main lateral load resisting system, since the internal pressure acting on the windward and leeward walls are equal and opposite. (Refer to Article 4.1.7.1(2) which does not discuss internal pressures).

Information on the selection of interior pressure coefficients, C_{pi}, for design purposes can be found in Commentary I of the "User's Guide – National Building Code 2005 Structural Commentaries (Part 4 of Division B)".

Exercise #6-7

Read Sentence 4.1.7.1.(3).
Complete the following exercise then discuss the answers with your group.

1. Using the Code, it has been determined that the external static wind pressure on an exterior wall is 0.75 kPa on the windward face of a warehouse *building*. The *building* has openings through which gusts may be transmitted, therefore it has also been determined that a range of internal pressure coefficients, C_{pi}, varying from –0.7 to +0.7 is appropriate for design. What is the net specified wind pressure that must be used for the design of the wall, assuming that $q = 0.40$ kPa, $C_e = 1.0$, $C_{gi} = 2.0$, and $I_w = 1.0$?

   a) 0.19 kPa

   b) 0.75 kPa

   c) 1.31 kPa

   d) none of the above

   OBC Reference(s): ____________________

STOP

6.6 INTERIOR WALLS AND PARTITIONS

Unbalanced air pressure may occur on interior *loadbearing* and non-*loadbearing* walls and *partitions*, which must be accounted for in their design. The Code provisions requirements are given in Article 4.1.7.4.

Commentary I of the "User's Guide – National Building Code 2005 Structural Commentaries (Part 4 of Division B)" gives background information on determining interior design pressures. The reader is reminded that the Commentaries do not form part of the examination syllabus.

Exercise #6-8

Read Article 4.1.7.4.
Complete the following exercise then discuss the answers with your group.

1. Which of the following are not factors affecting the design wind pressure on interior walls and partitions, according to the Code?

   a) differences in external pressure on the windward and leeward sides of a building

   b) differences in temperature between the interior and exterior of building

   c) possible live loads associated with guards

   d) mechanical pressurization of occupied space within a building

   OBC Reference(s): ____________________

STOP

6.7 FULL AND PARTIAL WIND LOADING

The pressure coefficients used for determination of equivalent static wind loads generally assume that the wind acts along the main principal axes of a building. In order to account for the likelihood that wind will occur at other directions, consideration of some wind acting simultaneously in both principal directions is required by the Code.

Article 4.1.7.3 gives the specific requirements for pattern loading of wind. These patterns are illustrated in Figures 6:4 to 6:7.

As discussed in Module 5, the requirement for patterning of loads on *buildings* accounts for the effects on the structure of partial loading that could be more structurally significant than full loading.

Further background on the application of full and partial wind loading can be found in Commentary I of the "User's Guide – National Building Code 2005 Structural Commentaries (Part 4 of Division B)".

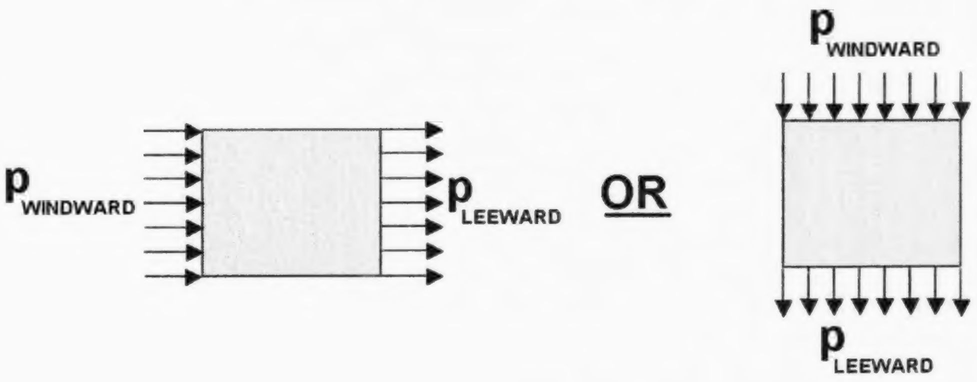

Figure 6:4
Plan View, Full Wind Loading on Principal Axes, Considered Separately – Clause 4.1.7.3.(1)(a)

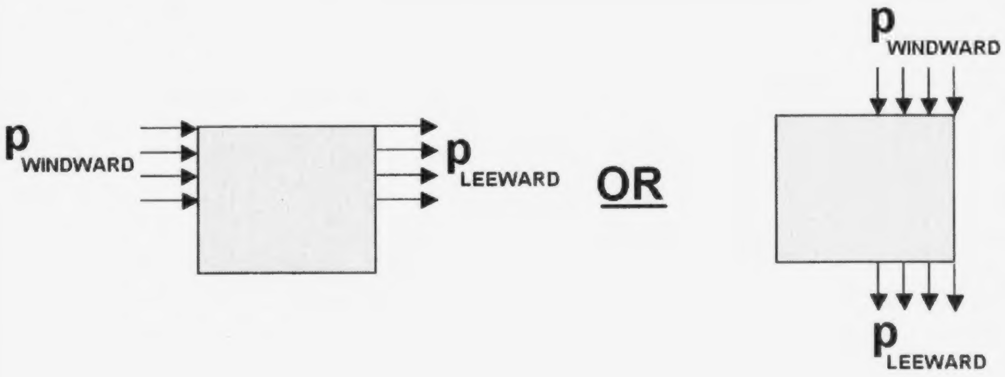
p WINDWARD
p LEEWARD
OR
p WINDWARD
p LEEWARD

Figure 6:5
Plan View, Full Wind Loading on Partial Wall Faces, Considered Separately
– Clause 4.1.7.3.(1)(b)

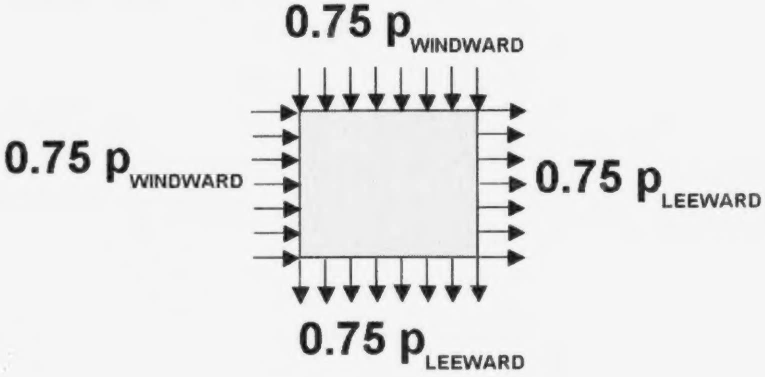
0.75 p WINDWARD
0.75 p WINDWARD
0.75 p LEEWARD
0.75 p LEEWARD

Figure 6:6
Plan View, 75% of Full Wind, Applied in Both Directions Simultaneously
– Clause 4.1.7.3.(1)(c)

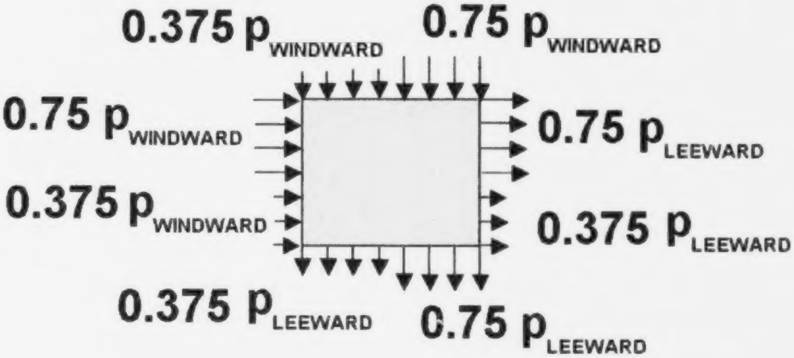
0.375 p WINDWARD
0.75 p WINDWARD
0.75 p WINDWARD
0.75 p LEEWARD
0.375 p WINDWARD
0.375 p LEEWARD
0.375 p LEEWARD
0.75 p LEEWARD

Figure 6:7
Plan View, 50% of Full Wind Removed From Part of Projected Area – Clause 4.1.7.3.(1)(d)

Exercise #6-9

With reference to Article 4.1.7.3, complete the following exercise then discuss your answers with the group.

1. If a *building* is to be constructed with its principal axis in the north-south direction, which of the following is a mandatory wind loading pattern to be considered in *building's* design?
   - a) 100% of the full wind load in the north-south direction and 100% of the full wind load in the east-west direction, acting at the same time
   - b) 100% of the full wind load in the north-south direction and 100% of the full wind load in the east-west direction, acting as separate load cases
   - c) 75% of the full wind load in the north-south direction and 75% of the full wind load in the east-west direction, as separate load cases
   - d) 100% of the full wind load in the north-south direction and 25% of the full wind load in the east-west direction, acting at the same time

   OBC Reference(s): ____________________

STOP End of Module 6

MODULE 7

EARTHQUAKE LOADS

BUILDING STRUCTURAL – 2006

7.0 INTRODUCTION

In this Module, we will learn how to determine the minimum earthquake loads required by the Building Code, as well as special Code provisions pertaining to buildings and components of buildings.

In reading the material in this Module, the reader may find it helpful to refer to the notation given in Article 4.1.8.2. Some of the terms used are specific to earthquake design and are not defined elsewhere in the Code.

This Module does not cover the engineering principles associated with earthquake design, but is limited to the finding, understanding and application of Building Code requirements. If additional background on the subject matter is desired, it may be found in Commentary J of the "User's Guide - National Building Code 2005 Structural Commentaries (Part 4 of Division B)". The material in the User's Guide does not form part of the examination syllabus.

7.1 OBJECTIVES

Upon completion of this Module participants will be able to:

- Find regional seismic data for various locations in Ontario
- Determine which method of earthquake load determination is applicable to a particular building
- Identify the component factors affecting earthquake load determination using the Building Code
- Verify calculations used to determine earthquake loads
- Identify specific earthquake provisions that apply to buildings and portions of buildings

Among the new requirements for earthquake design are requirements for complete load paths, separation of stiff nonstructural elements, and the introduction of definitions of irregular structures and special design requirements associated with these irregularities.

7.2 EARTHQUAKE LOAD AND EFFECTS

An earthquake is caused by a sudden grinding slippage between two parts of the earth's crust, which propagates motions in the surrounding ground. These ground motions occur in a random manner in both horizontal and vertical directions, and may cause damage to buildings through any of the following: ground shaking, soil failure (liquefaction or landslides) caused by shaking, effects of surface fault ruptures on structures, or tsunamis. Buildings are inherently strong in the vertical direction since they are designed to resist the vertical loads due to gravity, but they are relatively weak in the horizontal direction. Thus, the horizontal forces and deformations assume a dominant role in earthquake engineering for buildings. There is an obvious similarity to the horizontal forces imposed by wind, and indeed protection against wind may sometimes constitute a large portion of the protection needed against earthquakes. However, buildings are usually designed to deform elastically up to the design wind load, whereas some inelastic deformation is expected at the design earthquake load (i.e., attention must be given to the ductile performance of the structure).

Even though design forces for wind may be greater than seismic design forces in some situations, seismic detailing may be required. Even if wind forces do govern, the design must accommodate at least the type of lateral-load-resisting system and the detailing that correspond to the seismic forces calculated for the building.

The main factors that control building failure due to earthquake motions are:

- Seismicity
- Integrity of structure
- Lateral strength/ductility of structure
- Lateral stiffness of structure
- Building irregularities
- Ground conditions

Several factors that are detrimental to satisfactory seismic performance, which can lead to serious damage, collapse and danger to occupants are:

- A weak first storey
- Unstable foundation soils
- Unrestrained furnishings, components and appliances

Division B, Subsection 4.1.8. addresses building earthquake performance in broad terms of ground motions, site soil effects, analysis and design. It further divides the design requirements into load-reduction factors and a series of requirements. These requirements have been organized as follows:

1. Analysis
2. Notation
3. General Requirements
4. Site Properties
5. Importance Factor
6. Structural Configuration
7. Methods of Analysis
8. Direction of Loading
9. Force Reduction Factors, Overstrength, and General Restrictions
10. Other System Restrictions
11. Equivalent Static Force Procedure
12. Dynamic Analysis Procedure
13. Deflections and Drift Limits
14. Structural Separation
15. Design Provisions
16. Foundation Provisions
17. Elements of Structures, Nonstructural Components, and Equipment

Notes:

STOP

7.3 GENERAL REQUIREMENTS

Earthquakes release a tremendous amount of energy through the earth in waves. Theses waves of energy are called seismic waves. Seismic waves cause the ground to tremble and shake during an earthquake. As the earthquake's ground motions pass under a structure, they impact kinetic energy into the structure. This energy propagates in all directions and enters a structure as ground motion which has displacement, velocity, and acceleration components. Through its design and construction, the structure must absorb and control this energy as it is dissipated throughout the structure. Energy dissipation shows itself mainly as inelastic behaviour of the structural system.

An earthquake resistant structure should dissipate seismic energy as damage in the structural system, but collapse should not occur. After the earthquake, the damage should be economically feasible to repair. Observations reveal that beam-column joints and column ends are wrong locations to dissipate seismic energy. Similarly, shear failures and anchorage failures of reinforcing bars are wrong types of damage which dissipate very little energy and can lead to collapse. Furthermore, short columns and soft or weak stories must be strictly avoided. In earthquake prone regions, shear walls have proven to very effective in preventing building collapse due to earthquake energies.

The Building Code considers strong ground shaking to be a rare occurrence in Ontario. Division B, Article 4.1.2.1. defines earthquake loads as rare loads. Although stronger shaking can occur, in most situations it is typically economically impractical to design for such rare ground motions; hence for Ontario, the 2% in 50 year level may be termed the maximum earthquake ground motion to be considered, or more simply the design ground motion.

Division B, Article 4.1.8.3. contains a number of general requirements that are applicable to the analysis and design of buildings for the effects of earthquakes. These general requirements are fundamental building requirements that experience over the years with earthquakes has shown to be important for good building performance. The following is a generalized summary of the provisions:

- *Design* - Ensure that the structure conforms to both Subsection 4.1.8. and the applicable design standards referenced in Section 4.3. [Sentence 4.1.8.3.(1)]

- Load Path - Design structure so that it incorporates a systematic approach (i.e., load path) for transferring inertial forces generated in the more massive portions of the building (i.e., floor slab) to columns or walls that are continuous to the foundation of the structure. [Sentence 4.1.8.3.(2)]

- *SFRS* - The elements in the load path, which are designed and detailed to resist the earthquake load, must be clearly identified as being the seismic force resisting system (SFRS) and must be designed to resist 100% of the earthquake loads. The SFRS acting alone is used to calculate displacements. [Sentence 4.1.8.3.(3), (4)]
    - *Non-SFRS* - Structural framing members that are not part of the force resisting system must retain their integrity while supporting the gravity loads for which they were designed. It must be shown that these members behave elastically, or if their deformations are inelastic, that their load-carrying capacity not be at risk. [Sentence 4.1.8.3.(5)]
    - *Stiff non-SFRS* - Often there are stiff elements in a building such as concrete, masonry, brick, or precast walls or panels that are not part of the SFRS. These have the potential for affecting a building's response (i.e., interfering with its expected behaviour) and must be separated by gaps or sliding joints so that they do not interfere with the structure as it displaces, or they must meet the requirement of the SFRS and be made part of it. [Sentence 4.1.8.3.(6)]
    - *Non-SFRS* - The Building Code identifies three particular situations involving Non-SFRS elements that are not designed for seismic resistance that

contribute stiffness to the building structure:
(1) Elements that decrease the structural period by more than 15%,
(2) Elements that effect the irregularity of a structure, and
(3) Elements that have an adverse effect on the SFRS (i.e., elements that change the load path causing some parts of the SFRS to be subject to higher forces and/or deformations. [Sentence 4.1.8.3.(7)]

- *Structural Modelling* - Some structures, like steel buildings, are light and flexible enough to dissipate the seismic energy through non destructive movement. However, in larger and heavier buildings as their weight (mass = weight/gravity) increase, and as their height (moment arm) increases, greater forces can enter the structure resulting in higher levels of energy which must be dissipated.
  - *SFRS Design* - Structural modelling of the SFRS must incorporate a realistic representation of the magnitude and distribution of building mass and structural stiffness and must account for:
    (1) The effects of cracked sections (i.e., the determination of lateral deflections as specified in Article 4.1.8.13.),
    (2) The effects of finite sizes of members and joints (i.e., the calculation of torsional sensitivity, as specified in Sentence 4.1.8.11.(9),
    (3) The sway effects arising from the interaction of gravity loads with the displaced configuration of the structure (i.e., the determination of the fundamental period of the structure, as specified in Clause 4.1.8.11.(3)(d), and
    (4) Other effects that influence the lateral stiffness of the building (i.e, lateral stiffness is a particularly important parameter for two reasons:
      (i) the earthquake-induced load on the building is a direct function of the natural period, which itself is a direct function of lateral stiffness, and

(ii) lateral stiffness is a major determinant of lateral displacement, which governs structural performance.

Notes:

STOP

7.4 SITE PROPERTIES

In this next section we will explore the determination of the design spectral acceleration value:

For T=0.2 seconds:

$$S(T) = F_{a.}S_a(0.2)$$

For T=0.5 seconds:

$$S(T) = the\ lessor\ of$$

$$F_vS_a(0.5),\ and$$

$$F_aS_a(0.2)$$

For T=1.0 seconds:

$$S(T) = F_vS_a(1.0)$$

For T=2.0 seconds:

$$S(T) = F_vS_a(2.0)$$

For T≥4.0 seconds:

$$S(T) = \frac{F_vS_a(2.0)}{2}$$

Where:

$S(T)$ is the design spectral acceleration values at intermediate values of T

F_a is the acceleration-based site coefficient determined from Table 4.1.8.4.B

F_v is the velocity-based site coefficient determined from Table 4.1.8.4.C

S_a is the 5% damped spectral acceleration, expressed as a ratio to gravitational acceleration, for a period of T seconds and is obtained from Table 1.2 in SB-1.

Before we can start using these formulae, it is useful to look at the various attributes of earthquake design that are considered in this analysis.

Peak Ground Acceleration (PGA)

Peak ground acceleration (PGA) is a measure of earthquake intensity. Unlike the Richter magnitude scale, it is not a measure of the total size of the earthquake, but rather how hard the earth shakes in a given location. Peak ground acceleration must be measured against gravity, g (the acceleration due to gravity or m/s^2). Ground acceleration is not unlike the feeling we have when a vehicle takes off at high speed.

In order to measure the acceleration of an earthquake, it must be measured against gravity (i.e., 1.0g). Gravity is the rate at which an object falls when dropped from being at rest in a vacuum. It is quite a high rate of acceleration (i.e., approximately the same as a car travelling 100 metres from rest in just 4.5 seconds). The 1997 Building Code listed ground acceleration for various location into four zones. If a location was in seismic zone 4, you had a one in ten chance that an earthquake with an active peak acceleration level of 0.04g (i.e, 4/10 the acceleration of gravity) will occur within the next fifty years. For Vaughan the seismic zone, Z_a, in the 1997 Building Code was 1 (i.e., 0.01g).

The seismicity data found in the 1997 Building Code comprised data acquired up to 1977. There have been many earthquakes since 1977, and additional seismicity data has been compiled which has improved understanding of the geographical patterns of earthquake occurrence, and the ability to estimate earthquake occurrence rates as a function of earthquake magnitude. Returning to our example of the peak acceleration level for Vaughan, the 2006 Building Code now recommends a PGA of 0.150 (i.e., 0.150g). However, the probability level has been relaxed to be more consistent with the rare events for which damage, short of collapse, is tolerable. A level of 2% in 50 years has been chosen for the data in the 2006 Building Code [4.1.8.4.(1)].

Average Shear Wave Velocity ($\overline{V}_s$)

Site conditions play a major role in establishing the damage potential of incoming seismic waves from large earthquakes. The site class categories in Table 4.1.8.4.A. are defined in terms of the small-strain shear wave velocity in the top 30 m of the soil profile, $\overline{V}_s$, as might be inferred from travel time for a shear wave to travel from the surface to a depth of 30 m. If shear wave velocities are available for the site, they should be used to classify the site.

Alternative definitions of site class ($\overline{N}_{60}$), (S_u)

In recognition of the fact that in many cases the shear wave velocities are not available, alternative definitions of the site classes are also included in Table 4.1.8.4.A. They use the standard penetration resistance for cohesionless and cohesive soils and rock and the undrained shear strength for cohesive soils only. It is important to note that the site category definitions should not be interpreted as implying any specific numerical correlation between shear wave velocity and the standard penetration resistance or shear strength.

Acceleration-based site coefficient and velocity-based site coefficient (F_a *- short period site coefficient {at 0.2 second period}),* (F_v *- long period site coefficient {at 1.0 second period})*

The alternative definitions of the site classes (i.e, $\overline{N}_{60}$ and S_u) are rather conservative since the correlation between site amplification and these geotechnical parameters is more uncertain than the correlation with $\overline{V}_s$. That is, there will be cases where the values of F_a and F_v will be smaller if the site class is based on $\overline{V}_s$ rather than on the geotechnical parameters.

Design spectral acceleration values ($S(T)$)

Spectral acceleration parameters are coefficients corresponding to spectral accelerations in terms of g, the acceleration due to gravity. Where:

$S(T) = F_a S_a$ is the maximum considered earthquake, 5 percent-dampped, spectral response acceleration parameter at short periods adjusted for site class effects, and

$S(T) = F_v S_a$ is the maximum considered earthquake, 5 percent-dampped, spectral response acceleration parameter at a period of 1 second adjusted for site class effects.

EXERCISE № 7-1

Complete the following exercise, then discuss your answers with your group.

1. The average shear wave velocity for a site has been determined to be 500 m/s and the reported average standard penetration resistance of the soil is 45. According to the Building Code, what is the site class for this site?

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2. If the building site in question #1 had a single 4 m thick layer of organic clay within the upper 30 m of the soil profile, what would the site class be for this site?

3. Consider a proposed development site in Kingston. The average shear wave velocity for the site in question has not been determined. The average standard penetration resistance for the site is 35. Determine both the acceleration-based and velocity-based site coefficients for the site.

4. Consider the site in question #3 and calculate the design spectral acceleration values of $S(T)$.

5. Is the building site in question #4 exempt from the earthquake provisions of the Building Code?

STOP

Notes:

Highly variable subsurface conditions beneath a building footprint could result in overly conservative or unconservative site classification. Isolated soft soil layers within an otherwise firm soil site may not affect the overall site response if the predominant soil conditions do not include such strata. Conversely, site response studies have shown that continuous, thin, soft clay strata may increase the site amplification.

Buildings on sloping bedrock sites and/or having highly variable soil deposits across the building area require careful study since the input motion may vary across the building. Site-specific studies including two- or three-dimensional modelling may be appropriate in such cases to evaluate the subsurface conditions and site and superstructure response.

7.5 IMPORTANCE FACTOR

ULS - denotes Ultimate Limit States

SLS - denotes Serviceability Limit States

Because earthquake loads are considered rare events, there is no general requirement for design at the SLS level and no SLS importance factors are given in Table 4.1.8.5. However, post-disaster buildings must retain their capability to function following a major earthquake. So, rather than requiring SLS design for such buildings, their capability to continue to function is enhanced by specifying an operational, performance-level, interstorey lateral deflection limit that is only 40% of that specified for normal buildings.

The Building Code identifies four importance categories for buildings based on intended use and occupancy. The use of the earthquake importance factor (I_E) is to act as a multiplier in the calculation of the base shear, V, as specified in Division B, Sentence 4.1.8.11.(2).

Values of $I_E > 1.0$ have the effect of increasing the design spectral acceleration $S(T)$ for high and post-disaster buildings.
The use of an earthquake importance factor greater than 1.0 increases the design force level. It can be thought of as increasing the earthquake resistance and the safety of a structure or designing for an earthquake associated with a longer return period. Regardless as to how it is interpreted, the intent is to enhance the safety and performance of important structures.

Importance categories are based on the occupancy of the structures within the category and the relative consequences of earthquake-induced damage to the structures. In terms of post-earthquake recovery and redevelopment, certain types of occupancies are vital to public needs. In terms of disaster preparedness, regional communication centers identified as critical emergency services should be in a higher classification than retail stores, office buildings, and factories.

Post-Disaster Category
Post-disaster structures are those having essential facilities that are required for post-earthquake recovery. Also included are structures that contain substances, that if released into the environment, are deemed to be hazardous to the public. It is important to note that the importance factor of 1.5 is not intended to cover the design considerations associated with special purpose structures, such as facilities for the manufacture or storage of toxic materials, whose failure could endanger the lives of a large number of people or affect the environment well beyond the confines of the building. These types of structures may require more sophisticated analysis. In rural locations where there may not be a

major hospital, the principal authority may choose to require outpatient surgery clinics to be designated in this category.

Examples of post-disaster category structures include:

- Fire, rescue, and police stations
- Hospitals
- Designated medical facilities having emergency treatment facilities
- Designated emergency preparedness centers
- Designated emergency operation centers
- Designated emergency shelters
- Power generating stations or other utilities required as emergency back-up facilities for this category of use
- Emergency vehicle garages and emergency aircraft hangars
- Designated communication centers
- Aviation control towers and air traffic control centers
- Structures containing sufficient quantities of toxic or explosive substances deemed to be hazardous to the public
- Water treatment facilities required to maintain water pressure for fire suppression.

High Category

High structures are those having a large number of occupants and those where the occupants' ability to exit is restrained. The potential density of public assembly uses in terms of number of people warrant an extra level of care. The level of protection warranted for schools, day care centers, and medical facilities is greater than the level of protection warranted for occupancies where individuals are relatively self-sufficient in responding to an emergency.

Examples of high category structures include:

- Covered structures whose primary occupancy is public assembly
- Educational structures through the 12th grade
- Day care centers
- Medical facilities with incapacitated patients not otherwise designated as post-disaster
- Jails and detention facilities

- Power generating stations and other public utility facility not included in the post-disaster category, required for continued operation
- Water treatment facilities required for primary treatment and disinfection for potable water
- Waste water treatment facilities required for primary treatment

Low Category

Low category structures are basically farm buildings or very low occupancy, low-risk structures (i.e., bulk storage sheds such as highway salt sheds).

Normal Category

Normal category include structures of all other uses not included in the other categories.

Structures having multiple uses must be assigned the importance category of the use having the highest importance category, except that in structures having two or more portions which are structurally seismically separated, each portion can be separately categorized. Where a structurally seismically separated portion of a structure provides access to, egress from, or share life safety components with another portion having a higher importance category, the lower importance category portion must also be assigned the same category rating as the higher. Where operational access routes to higher category structures might be affected by falling debris from near by buildings with lower category designations, due consideration of these scenarios should be investigated.

Notes:

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STOP

7.6 STRUCTURAL CONFIGURATION

Structural configuration considers diaphragm behaviour of the structure in terms of lateral and vertical force resisting systems capable of providing adequate strength, stiffness, and energy dissipation capacity to withstand the design ground motions within prescribed limits of deformation and strength demand. In Division B, Article 4.1.8.6. structures must be classified as regular or irregular, based on the plan and vertical configuration of the structure.

In applying the various provisions of this Article, site properties and the importance factor of the structure must first be established. As a starting point it is beneficial to determine the value for the following two formula:

$$I_E F_a S_a(0.2) \text{, and } I_E F_v S_a(1.0)$$

where,

I_E is the importance factor determined from Table 4.1.8.5.,

F_a is the acceleration-based site coefficient determined from Table 4.1.8.4.B,

$S_a(0.2) \, and \, S_a(1.0)$

is the 5% damped spectral response acceleration, expressed as a ratio to gravitational acceleration determined from Table 1.2 of SB-1

Article 4.1.8.6. and Table 4.1.8.6. define eight types of structural irregularities, and gives code users direction on how to deal with such structures. We will now take a closer look at each of these eight types of structural irregularities.

Type 1 - Vertical Stiffness Irregularity

A soft story is one in which the lateral stiffness is less than 70% of that in the storey above or less than 80% of th average stiffness of the three storeys above. An extreme soft story is one in which the lateral stiffness is less than 60% of that in the storey above or less than

70% of the average stiffness of the three storeys above.

A moment-resisting frame in which one storey is much taller than the adjacent is an example of a Type 1 irregularity. Another example is a shear wall with a significant reduction in wall length occurring at one of the floor levels (see figure 7-1).

Design Notes:
- 4.1.8.7. {i.e., Methods of Analysis}
- 4.1.8.10. {i.e., Additional System Restrictions}
- Appendix A {i.e., User's Guide - NBC 2005, Structural Commentaries (Part 4 of Division B)}

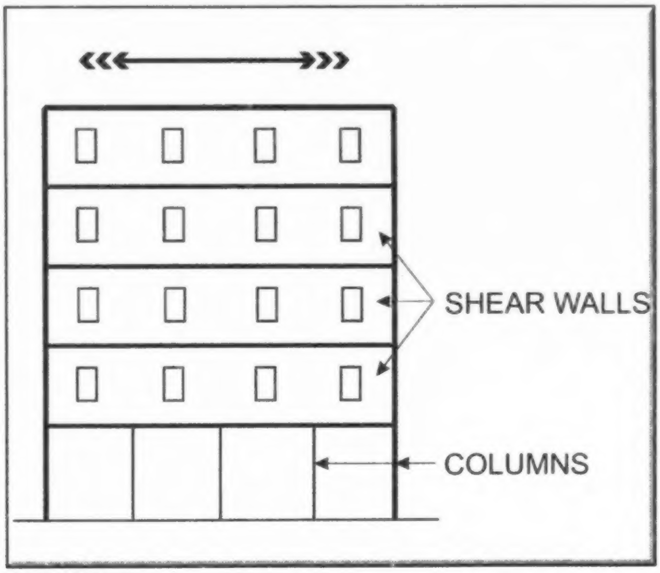

FIGURE 7-1 Example building elevation of a Type 1 Irregularity (i.e., Soft Storey)

Type 2 - Weight (mass) Irregularity
Mass irregularity is considered to exist where the effective mass of any storey is more than 150% of the effective mass of an adjacent storey. A roof that is lighter than the floor below need not be considered.

A thicker floor slab supporting an intermediate mechanical floor is an example of a Type 2 irregularity. Another example is the transition from a lighter superstructure with a residential occupancy to a more massive parking garage below.

Design Notes:

- 4.1.8.7. {i.e., Methods of Analysis}

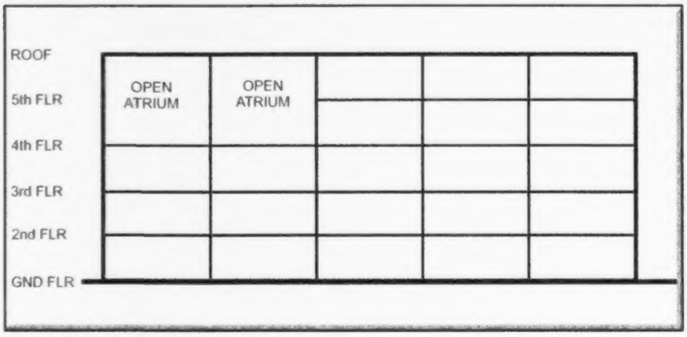

FIGURE 7-2 Schematic elevation view of a building with a Type 2 Mass Irregularity (i.e., the mass of the 4th floor exceeds 1.5 times the mass of the 5th floor)

Type 3 - Vertical Geometric Irregularity

Vertical geometric irregularity is considered to exist where the horizontal dimension of the lateral force resisting system (i.e., SFRS) in any storey is more than 130% of that in an adjacent storey.

An example of a Type 3 irregularity is a reduction in the overall dimensions of a central elevator/stairwell core assembly (which comprises the SFRS of the building) above a particular floor level. The stepping down of the dimensions of a moment-resisting frame below a certain floor level is another example. In many cases, such as in these examples, both Type 1 and Type 3 irregularities exist in the same SFRS.

Design Notes:

- 4.1.8.7. {i.e., Methods of Analysis}
- 4.1.8.10. {i.e., Additional System Restrictions}
- 4.1.8.15. {i.e., Design Provisions}
- Appendix A {User's Guide - NBC 2005, Structural Commentaries (Part 4 of Division B)}

Type 4 - In-Plane Discontinuity in Vertical Lateral-Force-Resisting Element

An in-plane offset of the lateral force-resisting elements (i.e., SFRS) greater than the length of those elements or a reduction in stiffness of the resisting element in the storey below.

An example of an in-plane offset is when a system of braces, wall or moment frames comes down between one set of column lines and at some level changes over to another set of column lines that is parallel to and collinear with the first set of columns. An example of a decrease in lateral stiffness below some level would be when a system of braces, wall or moment frames terminates at that level of the building. Another example would be the presence of openings in one storey of a wall with either no openings or smaller ones in the storey.

Design Notes:

- 4.1.8.7. {i.e., Methods of Analysis}
- 4.1.8.10. {i.e., Additional System Restrictions}
- 4.1.8.15. {i.e., Design Provisions}
- Appendix A {User's Guide - NBC 2005, Structural Commentaries (Part 4 of Division B)}

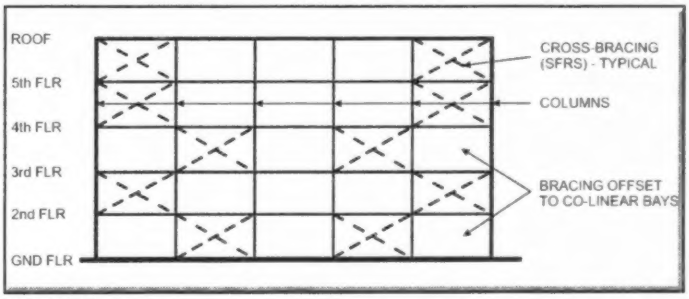
ROOF
5th FLR
4th FLR
3rd FLR
2nd FLR
GND FLR
CROSS-BRACING (SFRS) - TYPICAL
COLUMNS
BRACING OFFSET TO CO-LINEAR BAYS

FIGURE 7-3 Elevation view of building with a Type 4 In-Plane Irregularity.

Type 5 - Out-of-Plane Offsets

Discontinuities in a lateral force resistance path, such as out-of-plane offsets of the vertical elements of the SFRS.

An example of a Type 5 irregularity is a building that has a different spacing of column lines in its superstructure moment frame than in the frame of the parking garage below it. The relocation of the bracing in a steel frame from an exterior bay in lower storeys to an interior bay in upper storeys is another example.

Design Notes:

- 4.1.8.7. {i.e., Methods of Analysis}
- 4.1.8.10. {i.e., Additional System Restrictions}
- 4.1.8.15. {i.e., Design Provisions}
- Appendix A {User's Guide - NBC 2005, Structural Commentaries (Part 4 of Division B)}

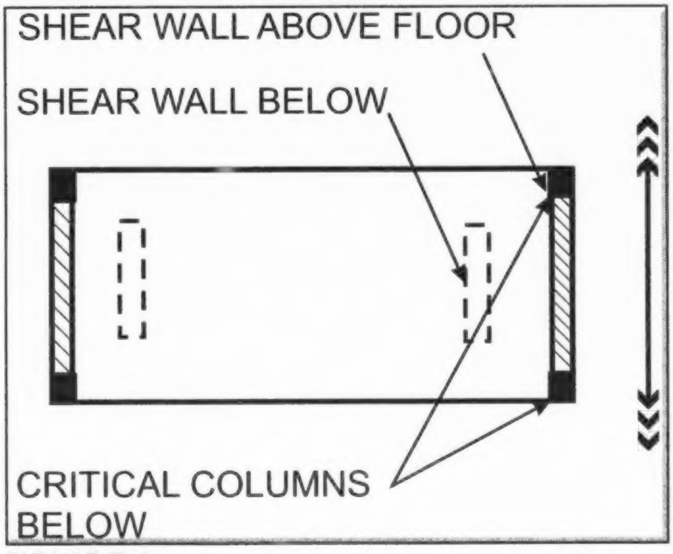

FIGURE 7-4 Plan view of building with a Type 5 out-of-plane offset irregularity (i.e., out-of-plane offset of the SFRS)

Type 6 - Discontinuity in Capacity - Weak Storey

A weak storey is one in which the storey shear strength is less than that in the storey above. The storey strength is the total strength of all seismic-resisting elements sharing the SFRS sharing the storey shear for the direction under consideration.

Given that there is normally a correlation between strength and stiffness, this type of irregularity is actually a special case or a variation of Type 4. The most common Type 6 irregularity occurs in the bottom storey of buildings where it is architecturally desirable to have large window openings to accommodate commercial occupancies.

Design Notes:

- 4.1.8.10. {i.e., Additional System Restrictions}

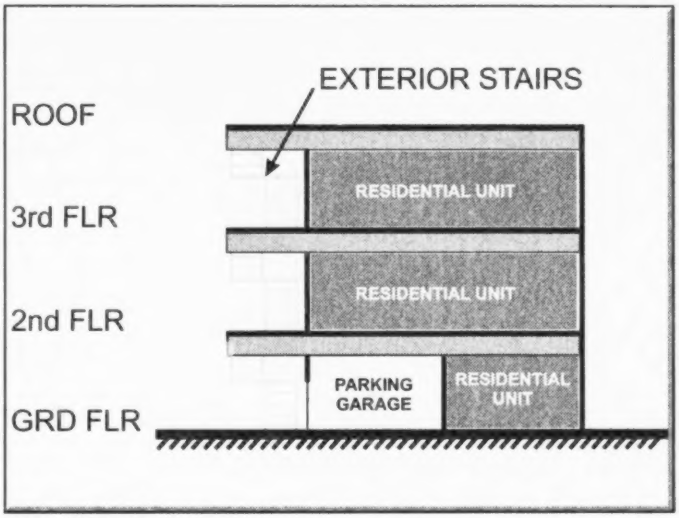
EXTERIOR STAIRS
ROOF
RESIDENTIAL UNIT
3rd FLR
RESIDENTIAL UNIT
2nd FLR
PARKING GARAGE
RESIDENTIAL UNIT
GRD FLR

FIGURE 7-5 Cross section of building with a Type 6 weak storey irregularity

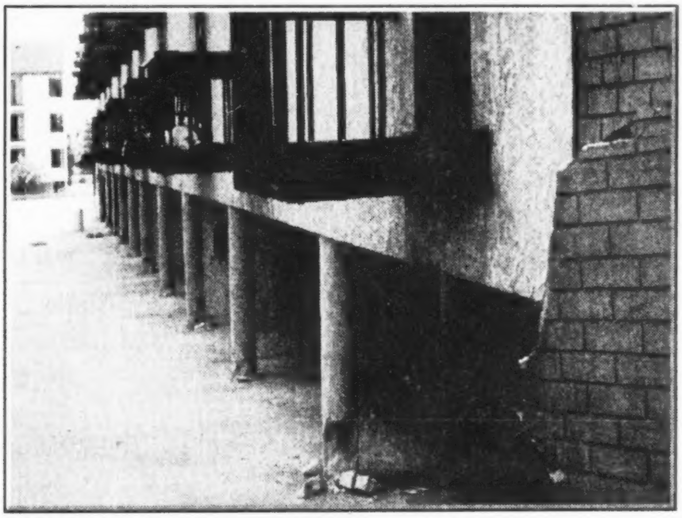

FIGURE 7-6 Type 6 weak storey irregularity

Type 7 - Torsional Sensitivity (to be considered when diaphragms are not flexible)

This type of irregularity exists when structures with rigid diaphragms are torsionally flexible (i.e., a flexible diaphragm may absorb torsional forces), leading to large torsionally induced displacements. Torsional sensitivity is considered to exist when the maximum displacement on a diaphragm in the direction of loading is 1.7 times the average displacement of the diaphragm in the direction of loading.

An SFRS comprising only a central core of elevator/stairwells exemplifies a torsionally flexible structural system.

Design Notes:

- 4.1.8.7. {i.e., Methods of Analysis}
- 4.1.8.10. {i.e., Additional System Restrictions}
- 4.1.8.15. {i.e., Design Provisions}
- Appendix A {User's Guide - NBC 2005, Structural Commentaries (Part 4 of Division B)}

Type 8 - Non-orthogonal Systems

This type of irregularity exists when the SFRS is not oriented along a set of orthogonal axes, which is the normal assumption with reference to the loads being considered to act independently along the two principal axes of the structure.

An example of a Type 8 irregularity is a Y-shaped plan with parallel sets of walls in each leg of the Y. The requirements for directions of loading that apply to this type of irregularity are given in Division B, Clause 4.1.8.8.(1)(b).

Design Notes:

- 4.1.8.8. {i.e., Direction of Loading
- Appendix A {Appendix A {User's Guide - NBC 2005, Structural Commentaries (Part 4 of Division B)}

These irregularities are used to trigger restrictions and special requirements elsewhere in the Subsection based on:

- the natural period or height of the building,
- whether the building is in a high or low seismic zone, and
- the importance category of the building.

The special requirements may include the following:

- the irregularity is not allowed,
- dynamic analysis must be performed,
- special capacity design procedures must be used on certain elements, and
- design forces must be increased.

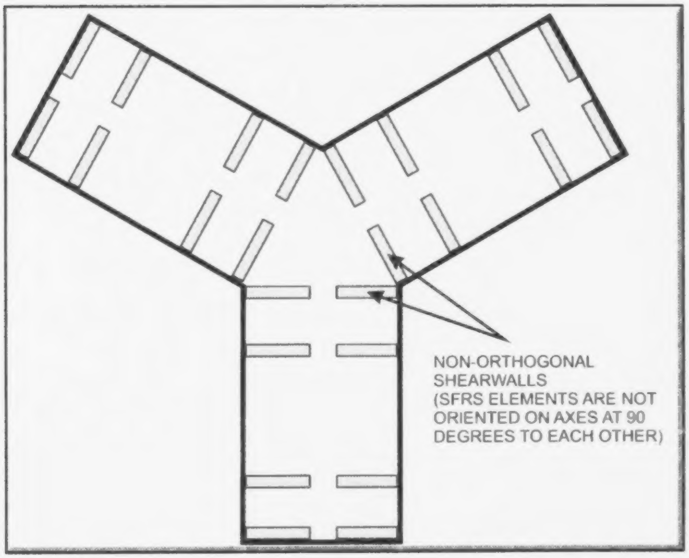
NON-ORTHOGONAL
SHEARWALLS
(SFRS ELEMENTS ARE NOT
ORIENTED ON AXES AT 90
DEGREES TO EACH OTHER)

FIGURE 7-7 Plan view of Type 8 non-orthogonal SFRS irregularity

NOTES:

STOP

EXERCISE № 7-2

Refer to Division B, Article 4.1.8.6. and answer the following questions:

1. According to the Building Code, when can a building be considered regular for the purposes of earthquake design?

2. Determine what Type of irregularity, if any, the following building descriptions most closely represent.

   (a) Consider a building where the weight of the second floor is 70% more than the weight of the third floor.

(b) In a 12 storey apartment building, a 6.0 m long shearwall that separates suites at all floors has a 3.0 m long opening at the ground floor level to create a larger lobby in the building.

(c) In a multi-storey building, columns form part of a moment-resisting frame (i.e., the SFRS). In the basement, the columns are vertically offset from the support columns below. The offset columns will be directly supported by large reinforced concrete transfer beams. (The basement is an underground parking garage and requires columns to be located in order to account for vehicle movement and parking.)

(d) The total shear resistance of the SFRS at the fifth floor is 40% larger than the shear resistance at the sixth floor, and the storey shear strength of the fifth floor is 20% more than the average storey shear strength of the sixth to eighth floors.

STOP

7.7 METHODS OF ANALYSIS

According to Article 4.1.8.7., the equivalent static force procedure can only be used where certain specific criteria are met. However, dynamic analysis can be used in all cases.

As we have seen, buildings are classified as being irregular when any one of a number of special features are present in the design. Such features include but are not limited to torsional plan irregularity (wherein the centre of mass does not coincide with the centre of resistance, causing the building to have a significant twisting component in its response to seismic loading), reentrant corner irregularity (wings in L-shaped building have a tendency to flap causing twisting in the building if they flap in phase and causing stress concentrations at the reentrant corner if they flap out-of-phase), vertical stiffness discontinuity (when the stiffness of a given storey is much higher or lower than the storey immediately above or below), vertical mass discontinuity (large mass difference between consecutive stories), etc.

According to Division B, Article 4.1.8.7., analysis for design earthquake actions must use a dynamic analysis procedure. However, under certain conditions, the equivalent static force procedure may be followed for the design of earthquake actions. It is important to note that even when Article 4.1.8.7. permits the use of an equivalent static force procedure, the building code identifies additional situations where a dynamic analysis is mandatory, for example:

- Site Class F - see Sentence 4.1.8.4.(5)
- Hybrid SFRS - see Note (4) to Table 4.1.8.11.
- Certain torsionally sensitive structures - see Clause 4.1.8.11.(10)(b)

The rationale for favouring the dynamic analysis procedure is that structures respond to earthquakes dynamically rather than statically (i.e., overall response parameters and their distribution within the structure are affected by the structure's dynamic properties and the input ground motion). By contrast, the equivalent static force procedure is only an approximate static simulation of that dynamic response and is reasonably accurate only in certain well defined circumstances. Lets take a closer look at the criteria of Division B, Sentence 4.1.8.7.(1).

Clause 4.1.8.7.(1)(a)
Values of $I_E F_a S_a(0.2) < 0.35$ represent relatively small ground motions on which the approximations inherent in the equivalent static force procedure are unlikely to have serious consequences.

Clause 4.1.8.7.(1)(b)
Structures classified as regular that are less than 60 m in height and have fundamental periods less than 2 seconds may be analysed using the equivalent static force procedure. Regular structures are inherently suited, in most circumstances, to static analysis.

Clause 4.1.8.7.(1)(c)
If the structure is less than 20 m in height and has a fundamental period of less than 0.5 seconds, the equivalent static force procedure is permitted for irregular structures, except for those with a Type 7 irregularity (i.e., torsional irregularity). Static analysis is permissible in these cases both because, for short period structures, irregularities have minimal effect on the dynamic response and the equivalent static force procedure specified in Division B, Article 4.1.8.11. is inherently somewhat conservative.

EXERCISE № 7-3

1. Refer to Division B, Article 4.1.8.7. and determine which method of analysis must be used for the follow structures.

    (a) The structure has an $I_E F_a S_a(0.2)$ of 0.23.

____

____

____

____

____

(b) The structure is 25 m in height and has a fundamental period of $T_a=0.5$ seconds in each principal direction. The $I_E F_a S_a(0.2)=0.35$ and the structure has a Type 7 irregularity.

(c) The structure is 55 m in height and has a fundamental period of $T_a=1.0$ seconds in each principal direction. The $I_E F_a S_a(0.2)=0.36$ and the structure has no irregularities.

(d) The structure is 25 m in height and has a fundamental period of $T_a=0.5$ seconds in each principal direction. The $I_E F_a S_a(0.2)=0.30$ and the structure has a discontinuity in capacity.

STOP

7.8 DIRECTION OF LOADING

Ground motion that causes earthquake deformations in buildings can occur in any direction. In general the directions of horizontal loading of a structure should be such as to produce the most unfavourable effect on any structural element. However, the code recognizes in Division B, Clauses 4.1.8.8.(1)(a) and (b) that for most building configurations, applying the specified loads independently along two orthogonal directions is sufficient.

Division B, Clause 4.1.8.8.(1)(c) recognizes that earthquake forces can act in both principal directions of the building simultaneously. However, the earthquake effects in the two principal directions are unlikely to reach their maxima simultaneously. This Clause provides a reasonable and adequate method of combining them. It requires that structural elements be designed for 100 percent of the effects of seismic forces in one principal direction combined with 30 percent of the effects of seismic forces in the orthogonal direction.

Here is the simplified formula representing the combination of effects of gravity loads, and effects of seismic forces according to Clause 4.1.8.8.(1)(c):

$$(A)\ gravity \pm 100\%\ of\ x(direction) \pm 30\%\ of\ y(direction)$$

$$(B)\ gravity \pm 30\%\ of\ x(direction) \pm 100\%\ of\ y(direction)$$

Note - The combination and signs (plus or minus) requiring the greater member strength are used for each member.

EXERCISE № 7-4

1. Refer to Division B, Article 4.1.8.8. and determine the method of analysis for the direction of earthquake forces in the following structures.

   (a) The structure is regular and the $I_E F_a S_a(0.2) = 0.20$.

   (b) The structure has a Type 8 irregularity and the $I_E F_a S_a(0.2) = 0.20$.

(c) The structure is regular and the $I_EF_aS_a(0.2)=0.40$.

(d) The structure has a Type 8 irregularity and the $I_EF_aS_a(0.2)=0.40$.

STOP

7.9 SFRS FORCE REDUCTION FACTORS, SYSTEM OVERSTRENGTH FACTORS, AND GENERAL RESTRICTIONS

The behaviour and performance of building structures in earthquakes is greatly dependent on the building shape, distribution of mass, continuity of load paths, and other factors pertaining to structural stiffness.

In addition, the structural materials and construction details greatly affect the ability of a building to dissipate energy in an earthquake. The Code does not generally dictate the types of structural systems or configurations that must be used, but instead, accounts for the behaviour of the various systems and configurations in assigning loads. However, Table 4.1.8.9. does not allow certain types of SFRS (i.e., see under Ductile moment-resisting frames, item "Other steel SFRS(s) not defined above and columns 6, 7 and 8 in the Table).

The part of a building that resists earthquake motions is called the seismic force resisting system (SFRS). The basic lateral and vertical seismic force resisting system (SFRS) must conform to one of the types indicated in Table 4.1.8.9. subject to the system limitations and height limits based on the short and long period spectral design acceleration triggers $I_E F_a S_a(0.2)$, and $I_E F_v S_a(1.0)$. Each type is subdivided based on types of vertical elements used to resist lateral seismic forces.

Seismic force resisting systems that are not contained in Table 4.1.8.9. are permitted by Sentence 4.1.8.9.(5), if analytical and test data are submitted that establish the dynamic characteristics and demonstrate the lateral force resistance and energy dissipation capacity to be equivalent to the structural systems listed in Table 4.1.8.9. for equivalent values of R_d and R_o.

For purposes of seismic analysis and design requirements, building framing systems are grouped in the structural categories:

- Steel Structures Designed and Detailed According to CAN/CSA-S16

- Concrete Structures Designed and Detailed According to CSA A23.3
- Timber Structures Designed and Detailed According to CAN/CSA-O86
- Masonry Structures Designed and Detailed According to CSA S304.1

For those cases where combinations of structural systems are employed, the engineer must use judgment in selecting appropriate force modification factors. For example, Sentence 4.1.8.9.(3) requires that the lowest value of R_dR_o be taken. The intent of Sentence 4.1.8.9.(3) is to prohibit support of one system by another possessing characteristics that result in a lower base shear factor (i.e., the entire system should be designed for the higher seismic shear). However, Sentence 4.1.8.9.(4) includes an exception to permit the use of such systems as a braced frame penthouse on a moment frame building in which the mass of the penthouse does not represent a significant portion of the total building and, thus would not materially affect the overall response to earthquake motions.

The 1997 Building Code included the use of a force modification factor, R, in the denominator of the formula used to calculate the lateral earthquake force, V. This factor represented the capability of the structure to dissipate energy through hysteretic inelastic response during strong earthquake ground motions. For the 2006 Building Code, two force modification factors are used, R_d and R_o.

R_d is the ductility-related force modification factor reflecting the capability of a structure to dissipate energy through inelastic behaviour. R_d corresponds to the R in the 1997 OBC and ranges from 1.0 for the most brittle systems (i.e., unreinforced masonry) to 5.0 for the most ductile systems (i.e, steel or reinforced concrete ductile moment-resisting frames).

R_o is the overstrength-related force modification factor accounting for the dependable portion or reserve strength in a structure. The seismic load effect with overstrength is intended to address those situations where failure of an isolated individual, brittle element can result in the loss of a complete seismic force resisting system or in instability and collapse.

When ductile structures deform inelastically (i.e., permanently), significant seismic energy is dissipated. From Table 4.1.8.9. it can be seen that brittle or non-ductile structural systems (such as unreinforced masonry) have comparatively low values of R_d, meaning that such structures must, by necessity, be designed for comparatively higher earthquake loads.

These two factors are determined using the provisions of Article 4.1.8.9. and Table 4.1.8.9. In columns 4 to 8 of the Table, the designation:

- "NP" means that the SFRS described is not permitted,
- "NL" means that there are no height limitations to the use of the SFRS, and
- a numeric value represents the maximum height limits in m for the SFRS.

To determine whether a particular SFRS is allowed or limited in height by Table 4.1.8.9., it will be necessary to first calculate the modified short and long period spectral design acceleration triggers:

Short

$$I_E F_a S_a(0.2)$$

Long

$$I_E F_v S_a(1.0)$$

EXERCISE № 7-5

Read Article 4.1.8.9. and complete the following questions.

1. What are the related force modification factors for a building constructed using moment-resisting wood frames with limited ductility connections?

2. If the building in question #1 has a short period spectral design acceleration value of 0.2 and a long period spectral design acceleration value of 0.35, are there any restriction placed on the SFRS?

3. For a building that utilizing reinforced concrete shear walls for the SFRS, determine if the following design factors and general restrictions are in conformance with Article 4.1.8.9.:

   (a) $I_E F_a S_a(0.2) = 0.25$
   $I_E F_v S_a(1.0) = 0.25$
   No height limit for SFRS
   $R_d = 1.5$
   $R_o = 1.3$

   (b) $I_E F_a S_a(0.2) = 0.40$
   $I_E F_v S_a(1.0) = 0.35$
   Height limit for SFRS = 30 m
   $R_d = 3.5$
   $R_o = 1.6$

   (c) $I_E F_a S_a(0.2) = 0.75$
   $I_E F_v S_a(1.0) = 0..35$
   No height limit for SFRS
   R_d and $R_o = 1$

4. If the SFRS of a building consists of conventional moment-resisting reinforced concrete frames, and:
   - $I_E F_a S_a(0.2) = 0.85$
   - $I_E F_v S_a(1.0) = 0.29$,

   what are the force modification factors and general restrictions according to Article 4.1.8.9.?

5. Consider a single-storey school where half of the masonry shear walls (in each principal direction) are reinforced to provide moderate ductility, and the remaining masonry shear walls are unreinforced. The short period spectral design acceleration is 0.2 and the long period spectral design acceleration value is 0.35. According to Article 4.1.8.9., what are the required force modification factors and general restrictions for this building?

Note:

If the masonry shear walls are reinforced and have no ductility, the $R_d = R_o = 1.5$ for the building - see Sentence 4.1.8.9.(3) that requires the use of the lowest values of $R_d R_o$. However, as the question stands in this example, the proposed SFRS would not be permitted.

6. According to Article 4.1.8.9., what is the overstrength-related force modification factor R_o for a building with tension-only steel cross-braces for the SFRS as shown in the Figure 7-8?

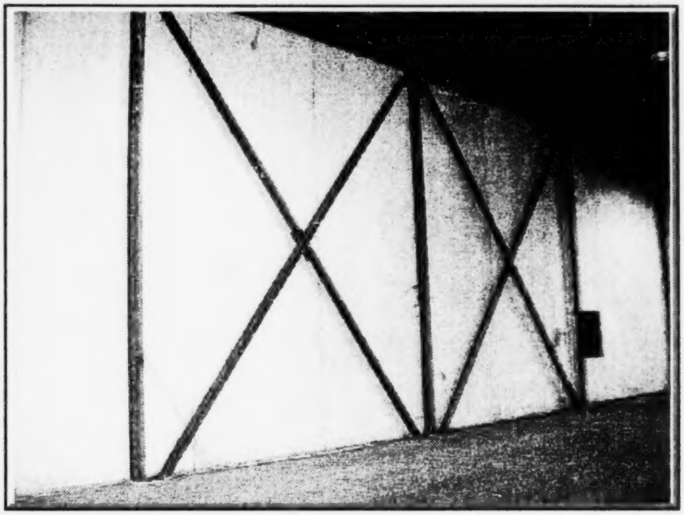

Figure 7-8

STOP

7.10 ADDITIONAL SYSTEM RESTRICTIONS

Article 4.1.8.10. sets out additional limitations on the selection of the seismic force resisting system. Structures with a discontinuity in capacity (i.e., weak storey Type 6 irregularity in Table 4.1.8.6.) are particularly vulnerable to damage and collapse during seismic ground motions.

Special consideration is given to post-disaster buildings through the specification of an importance factor I_E = 1.5. In addition, Sentence 4.1.8.10.(2) imposes other restrictions on the design of the seismic force resisting system for such buildings.

Table 7-1 summarizes the requirements of Article 4.1.8.10.

Notes:

Table 7-1

Row 1	Reference	Irregularity Type	$I_E F_a S_a(0.2)$	$I_E F_v S_a(1.0)$	R_d	T_a	Notes
2	4.1.8.10.(1)	Type 6	< 0.2	-	-	-	Type 6 irregularity permitted if forces used for design of SFRS are multiplied by $R_d R_o$
3	4.1.8.10.(1)	Type 6	≥ 0.2	-	-	-	Type 6 irregularity not permitted
4	4.1.8.10.(2)(a)	Type 1, 3, 4, 5, and 7	≥ 0.35	-	-	-	Type 1, 3, 4, 5, and 7 irregularity not permitted in post disaster buildings
5	4.1.8.10.(2)(b)	Type 6	-	-	-	-	Type 6 irregularity not permitted in post disaster buildings
6	4.1.8.10.(2)(c)	All	-	-	≥ 2.0	-	R_d of 2.0 or greater for SFRS not permitted in post disaster buildings
7	4.1.8.10.(3)	Type 4 or 5	-	> 0.25	-	≥ 1.0 s	Walls forming part of the SFRS shall be continuous from their top to the foundation and shall not have a Type 4 or 5 irregularity
8/1	**Column 2**						

7.11 EQUIVALENT STATIC FORCE PROCEDURE FOR STRUCTURES SATISFYING THE CONDITIONS OF ARTICLE 4.1.8.6.

As noted early in this Module, the dynamic analysis procedure is the default method of analysis in the 2006 Building Code and the equivalent static force procedure is permitted only if any of several specified criteria are met.

The equivalent static force procedure in the 2006 Building Code is similar in its basic concept to the equivalent lateral seismic force found in the 1997 Building Code, however, with several improved features being incorporated.

The equivalent static force procedure is based on the approximation that the effects of yielding can be adequately accounted for by linear analysis of the seismic force resisting system for the design spectrum, which is the elastic acceleration response spectrum reduced by the response modification factor, R_dR_0. In the equivalent static force procedure the distribution of seismic lateral forces over the height of the building is based on simplified formulas that are appropriate for regular structures as described in Article 4.1.8.7.

For a structure with a fundamental lateral period, T_a, the minium lateral earthquake force, V (i.e., often referred to as the design base shear) is to be calculated in accordance with the following formula:

$$V = \frac{S(T_a) M_v I_E W}{R_d R_o}$$

where,

$I_ES(T_a)$ is the importance modified design spectral acceleration, which when multiplied by the weight, W, represents the maximum force in an elastic single-degree-of-freedom system with a period T_a,

M_v is a multiplier that accounts for the participation of higher modes in the actual dynamic response of the structure (the product $S(T_a)M_vI_EW$ represents the maximum force in an elastic system with a fundamental period T_a), and

R_dR_o is the reduction factor, which accounts for both ductility and overstrength.

Although the design spectral acceleration, S(T), is specified in Sentence 4.1.8.4.(6) for periods greater than 2.0 s, there is considerable uncertainty associated with those values at such long periods. Sentence 4.1.8.11.(2) therefore specifies a minimum value of V (i.e., the design base shear),which corresponds to the value when T=2.0 s:

$$V_{\min imum} = \frac{S(2.0)M_vI_EW}{R_dR_o}$$

where the value of M_v must be that applicable for periods of 2.0 s or greater (see Table 4.1.8.11.).

The application of the formula for the calculation of V results in very high values of V at short periods compared with values computed using the 1997 Building Code formulation for a number of reasons. As a consequence, the 2006 Building Code includes an experience-based factor of 2/3, which is applied to limit forces in all but the most brittle structural systems. The base shear need not exceed the following value for an SFRS having a value of $R_d \geq 1.5$:

$$V_{\max imum} = \frac{2}{3} \times \frac{S(0.2)I_EW}{R_dR_o}$$

Inherent in the equivalent static force procedure are numerous assumptions regarding modes of structural vibration and the response of buildings to imposed deformations. The following list of topics will discuss the component factors in the equations found in Article

4.1.8.11.:

1. Fundamental lateral period, T_a,
2. Weight, W,
3. Higher mode factor, M_v and its associated base overturning moment reduction factor, J,
4. Distribution of the total lateral seismic force,
5. Overturning moment, M_x, and
6. Torsional Effects, B

The lateral earthquake design force V represents the code-specified earthquake horizontal force in an elastic system. The reduction factor $R_d R_o$ in the equations for V has the function of reducing the potential earthquake force used in designing the SFRS. It is important to note, that this reduction does not alter or change the actual forces caused by an earthquake. It is included so that the design of the SFRS will yield at a predetermined horizontal force. If however, the SFRS does not yield, the building will experience the unreduced earthquake design force.

1. Fundamental lateral period, T_a,

The static base shear expression includes the design spectral response acceleration computed at the fundamental lateral period, T_a, in the same direction as the loading being applied. In Division B, Sentence 4.1.8.11.(3), a procedure is given for determining the fundamental lateral period, T_a, of a building. Determination of this value is important, because it is a means by which the natural frequency of vibration of the building is accounted for.

The fundamental lateral period, T_a, must be determined for each principal direction that is consistent with the loading directions described in Article 4.1.8.8. Buildings with a large period are relatively flexible, and stiff buildings have a comparatively low value. Since the design earthquake forces depend greatly on the deformation properties of a building, it is very important that the value of T_a not be underestimated or overestimated.

Division B, Clauses 4.1.8.11.(3)(a) to (c) include formulae for moment-resisting frames, braced frames, shear wall and other structures. However, as an alternative, Clause 4.1.8.11.(3)(d) permits the use of structural modelling to determine the fundamental lateral period, T_a of a building. The code recognizes that structural modelling tends to produce longer periods than the ones in actual structures, because modelling usually does not take into account the participation of non-structural elements which tend to stiffen the structure. To guard against the computation of excessively long periods, Clause 4.1.8.11.(3)(d) requires that the computed periods be limited to the values determined by Subclauses 4.1.8.11.(3)(d)(I) to (iv).

2. Weight, W,

The weight, W, used in the base shear formula is calculated as the sum of the weights of each of the storeys. The earthquake force on a building or component of a building is an inertia force that is directly proportioned to the weight, W, as defined in Sentence 4.1.8.2.(1) of the building code.

3. Higher mode factor, M_v and its associated base overturning moment reduction factor, J,

In the equivalent static force procedure, the Building Code requires that a factor be used to account for the higher-modes of dynamic structural response, in order to model multi-degrees of freedom. The calculation of static base shear involves the transformation of the shear in a single-degree-of-freedom system to that in a multi-degree-of-freedom system.

Since higher mode effects tend to increase base shear in long period structures, it is necessary to compensate by reducing overturning moments. The higher mode factor, M_v, and its associated base overturning moment factor, J, are derived from Division B, Table 4.1.8.11.

In order to enter Table 4.1.8.11. to obtain values for M_v and J, the type of lateral resisting system must be known and the value of the following formula must be calculated:

$$\frac{S_a(0.2)}{S_a(2.0)}$$

For values of M_v between fundamental lateral periods, T_a, of 1.0 and 2.0, the product $S(T_a) \times M_v$ must be obtained by linear interpolation. Similarly, values of J between fundamental lateral periods, T_a, of 0.5 and 2.0 s must be obtained by linear interpolation.

4. Distribution of the total lateral seismic force

The total lateral seismic force, V, determined in accordance with Division B, Sentence 4.1.8.11.(2) represents the Building Code earthquake shear at the base of the building. This lateral seismic force, V, must be distributed along the height of the building in accordance with the provisions of Division B, Sentence 4.1.8.11.(7).

This is the form of the distribution formula (see Figure 7-9):

$$F_x = \frac{(V - F_t) \times W_x \times h_x}{\left(\sum_{i=1}^{n} W_i h_i\right)}$$

Where,

F_t - a portion of V concentrated at the top of the structure
$F_t = 0$ for $T_a \le 0.7$ s
$F_t = 0.07T_aV$ for $0.7\text{ s} < T_a < 3.6$ s
$F_t = 0.25V$ for $3.6\text{ s} < T_a$

F_x - lateral force applied at level x

h_i - the height above the base to level i, where the base of the structure is the level at which horizontal earthquake motions are considered to be imparted to the structure

h_x - the height above the base to level x, where the base of the structure is the level at which horizontal earthquake motions are considered to be imparted to the structure

W_i - portion of W that is located at or is assigned to level i

W_x - portion of W that is located at or is assigned to level x

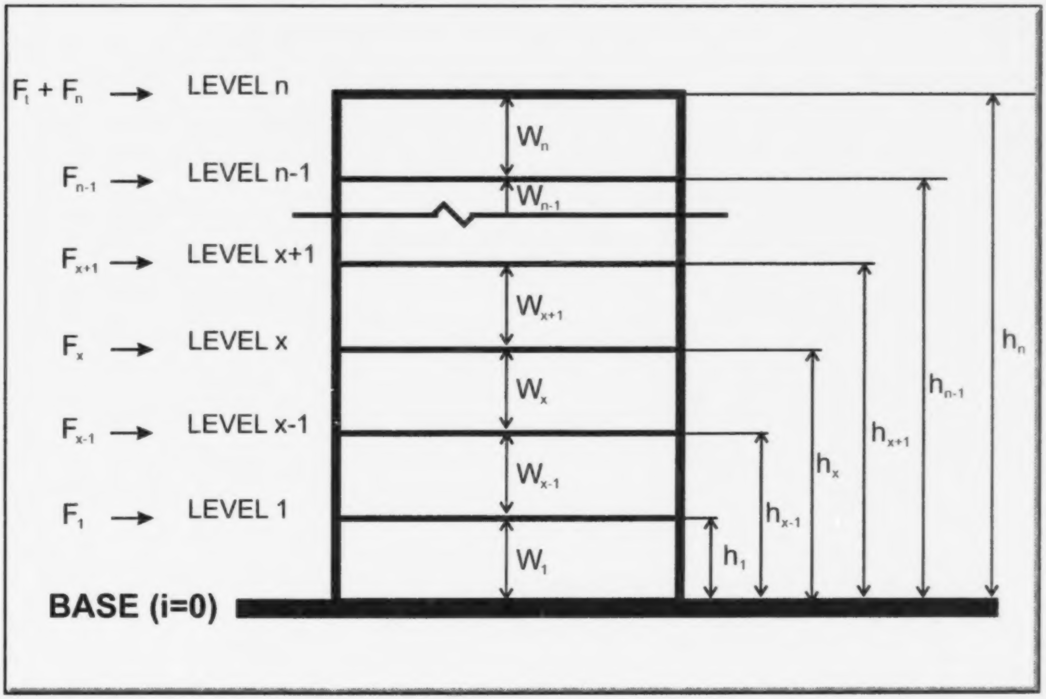
$F_t + F_n$ → LEVEL n
F_{n-1} → LEVEL n-1
F_{x+1} → LEVEL x+1
F_x → LEVEL x
F_{x-1} → LEVEL x-1
F_1 → LEVEL 1
BASE (i=0)
W_n
W_{n-1}
W_{x+1}
W_x
W_{x-1}
W_1
h_1
h_{x-1}
h_x
h_{x+1}
h_{n-1}
h_n

Figure 7-9 (note: Storey x is the storey immediately below level x)

EXERCISE № 7-6

Consider the following building description for all questions in Exercise № 6:

- Level 1 (At grade for this exercise)
  - 5 m above the base ($i=0$)
  - $W=13{,}000$ kN
- Level 2
  - 3.5 m above Level 1
  - $W=10{,}000$ kN
- Level 3
  - 3.5 m above Level 2
  - $W=10{,}500$ kN
- Level 4
  - 3.5 m above Level 3
  - $W=10{,}000$ kN
- Level 5 (Roof)
  - 3.5 m above Level 4
  - $W=14{,}000$ kN

1. Determine the fundamental lateral period, T_a, if the building SFRS consists of moment resisting frames that resist 100% of the required lateral forces.

2. If the site is located in Espanola, Ontario and the average shear wave velocity of the site is 250 m/s, determine the design spectral acceleration values for S(T).

3. If the moment resisting frames are of structural steel that have been designed to react in a ductile manner, determine the SFRS force reduction factor and system overstrength factor for the building. The structure is a residential, platinum members only, exclusive condominium building located in a prime area of Espanola.

4. If the SFRS of the structure consists of steel moment frames, determine the higher mode factor, M_v, and its associated base overturning moment reduction factor, J.

5. Using the results of questions 1 through 4, calculate the minimum lateral earthquake force, V at the base of the building.

6. Distribute the total lateral seismic force, calculated in question #5, vertically throughout the building.

Step 1 - complete computation table

Storey	Level (x)	h(x) (m)	W(x) (kN)	h(x) X W(x) (kN m)
Grnd	1	5.0	13,000	65,000
Second	2			
Third	3			
Fourth	4			
Fifth	5			
			$\sum_{i=1}^{n} W_i h_i$	

Step 2 - calculate F_t

___

___

Step 3 - complete distribution table

Level (x)	V - F_t (kN)	$W_x h_x$	$\frac{W_x h_x}{\sum_{i=1}^{n} W_i h_i}$	Force (x)
1	529.34	65,000	0.093	49.23
2				
3				
4				
5				

7. Using the distribution table in question #6, determine the storey shear at the 5th, 4th, 3rd, 2nd, and ground floors.

Storey Shear	
5th	
4th	
3rd	
2nd	
Grd	

STOP

5. Overturning Moment, M_x

In the design of a building as a whole for stability, and for the design of individual lateral load resisting elements, it is necessary to determine overturning moments caused by the horizontal storey shears. Overturning moments must be known at the base, as well as at all levels of the building. At any storey, the increment of overturning moment in the storey under consideration shall be distributed to the various vertical force resisting elements in the same proportion as the distribution of the horizontal shears to those elements.

Division B, Table 4.1.8.11. gives the overturning moment reduction factor, J, which is to be applied at the base of the structure in recognition of the overestimation of the higher mode effects on overturning moments. Not only does a reduction factor need to be applied to the base overturning moment but also to the overturning moments at other levels in the structure.

Division B, Sentence 4.1.8.11.(7) requires that the structure be designed to resist overturning moments statically consistent with the design storey shears. The overturning moment reduction factor, J, obtained from Table 4.1.8.11. is not applied to the top 40% of the height of the building and a linear variation occurs below that height to the base. The factor J_x is to be applied as a multiplier to the overturning moment normally computed at level x. Here is the formula that is to be used to calculate overturning moments at level x:

$$M_x = J_x \sum_{i=1}^{n} F_i (h_i - h_x)$$

where,

$$J_x = 1.0 \longrightarrow for\, h_x \geq 0.6h_n\ (i.e., top\, 40\%), and$$

$$J_x = J + (1 - J)\left(\frac{h_x}{0.6h_n}\right) \longrightarrow for\, h_x < 0.6h_n$$

$$F_i = the\ portion\ of\ the\ seismic\ base\ shear, V,$$
$$inducted\ at\ level\ i, and$$
$$h_i\ and\ h_x = the\ height\ from\ the\ base\ to\ level\ i\ or\ x$$

EXERCISE № 7-7

Using the information and tables from exercise #7-6, together as a group we will calculate the overturning moments for the structure.

Step One - gather applicable values required to complete the calculation

Level (x)	Storey Shear (kN)	Height h(x)
1		
2		
3		
4		
5		

Step Two - determine the location of the top 40%

____

____

Step Three - calculate the J_x for the various levels

Level (x)	J	J_x
1		
2		
3		
4		
5		

Step Four - calculate the overturning moment at base (x=0)

Level (x)	J_x	F (kN)	$h_i - h_x$	$F(h_i - h_x)$
1	.969			
2	.986			
3	1.0			
4	1.0			
5	1.0			
		$\sum_{i=1}^{n} F_i\left(h_i - h_x\right)$		

Calculate the overturning moment at level 3 (x=12)

Level (x)	J_x	F (kN)	h_i - h_x	$F(h_i - h_x)$
3	1.0			
4	1.0			
5	1.0			
			$\sum_{i=1}^{n} F_i(h_i - h_x)$	

6. Torsional Effects, B

Division B, Sentence 4.1.8.11.(8) requires that the design of the structure include the consideration of torsional effects concurrently with those due to the lateral static loads. Since the equivalent static force procedure is by definition an elastic method of analysis, the torsional effects described in Sentence 4.1.8.11.(8) assume elastic behaviour.

Torsion occurs in asymmetric structures when the centers of mass (at each level) do not coincide with the centers of structural rigidity at those levels. However, torsion may also occur in symmetric structures, due to uncertainty in the determination of the centers of mass and rigidity, inaccuracies in measured dimensions, variations in material properties, or even rotational seismic ground motion. An example of torsional deformations is shown in Figure 7-10.

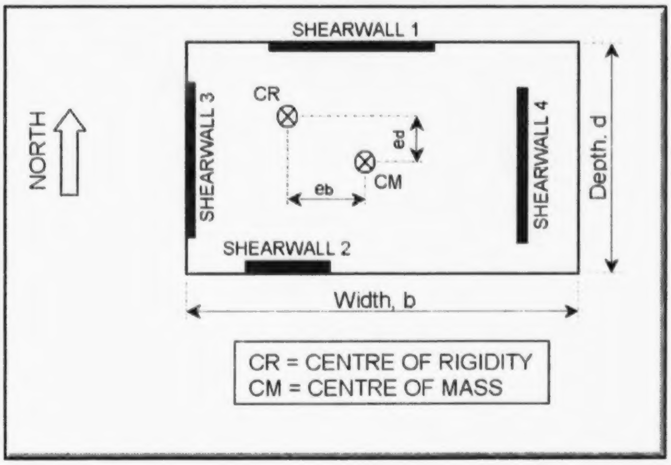

Figure 7-10

The effect of this eccentric loading, or torsion, is to cause a twisting action to occur in the building with respect to its vertical axis. This twisting action results in additional shears being exerted upon some of the lateral load resisting elements. These additional shears must be accounted for in the design of the building.

The code recognizes in Division B, Sentence 4.1.8.11.(9) that the torsional effects can be considered using static analysis if the structure does not have torsional sensitivity. A parameter B_x is calculated at each floor level. The torsional sensitivity parameter, B, for the entire building is the maximum of all of the values of B_x for both orthogonal directions of loading (except for one storey penthouses with weight less than 10% of the level below).

Torsionally stiff structures have small values of B and torsionally flexible structures have large values of B. For buildings with $B \leq 1.7$ (i.e., relatively stiff building), the torsional effects shall be derived from the formula in Division B, Clause 4.1.8.11.(10)(a). However, for buildings with $B > 1.7$ and $I_E F_a S_a(0.2) \geq 0.35$, Clause 4.1.8.11.(10)(b) requires that a dynamic analysis procedure be used.

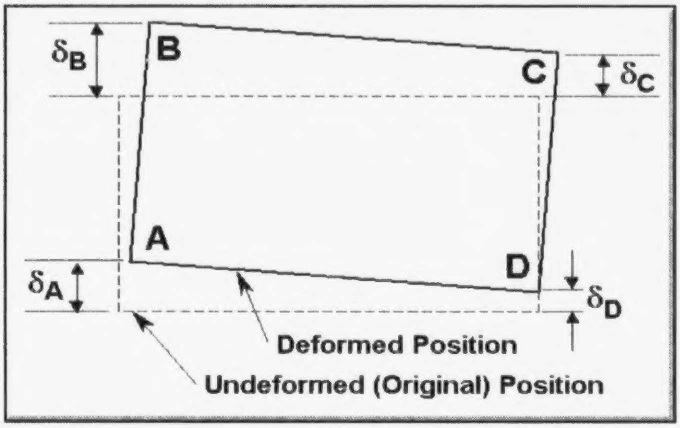

Figure 7-11

EXERCISE № 7-8

Figure 7-11 is a plan view of torsional deflections of a storey in a building. Together we will calculate the torsional sensitivity of this storey.

The horizontal deflections due to earthquake forces acting on this storey have been calculated to be:
$\delta_A = 20$ mm
$\delta_B = 40$ mm
$\delta_C = 15$ mm
$\delta_D = 5$ mm

STOP

7.12 DYNAMIC ANALYSIS PROCEDURE

The engineering principles associated with dynamic analysis are beyond the scope of this course. However, the reader should be familiar with the Code requirements that govern earthquake design using the dynamic procedure in Article 4.1.8.12.

Additional information on dynamic analysis may be found in Commentary J of the "User's Guide - National Building Code 2005 Structural Commentaries (Part 4 of Division B)".

Notes:

STOP

7.13 DEFLECTIONS, DRIFT LIMITS AND STRUCTURAL SEPARATION

In Module 3, the overall requirements of Part 4 regarding serviceability deflection (as stated in Division B, Article 4.1.3.5.) were discussed. When considering earthquakes, the deflection requirements of Article 4.1.8.13. apply.

Additionally, Article 4.1.8.14. gives requirements for adjacent buildings that are closely spaced, in order to prevent damage because of them "pounding" against each other in an earthquake. The building separation requirements in Division B, Sentence 4.1.8.14.(1), are based on the square root of the sum of the squares of the individual displacements from the absolute sum of the displacements.

When the lateral forces from an earthquake displace a building laterally, the gravity loads acting vertically downward cause an overturning moment on the structure about its base, in addition to the overturning moment caused by the lateral forces themselves. This second order effect which can lead to global instability of the building is termed the P-Delta effect. The Code in Article 4.1.8.13. is attempting to prevent large displacements and drifts due to earthquakes that contribute to damage to the nonstructural components, damage to the nonlateral load-carrying elements, and P-Delta effects.

Implicit in Sentence 4.1.8.13.(3) is the expectation that for the very rare earthquake event (i.e., 1 in 2500 year return period) the building could be in a state of near collapse, but not collapsed. The provisions of Sentence 4.1.8.13.(3) set the near-collapse drift limit at $0.025h_s$.

EXERCISE № 7-9

Consider the two adjacent office buildings shown in Figure 7-12 and calculate the drift limits and minimum horizontal separation between the two buildings.

- The SFRS for both buildings are concrete shear walls.
- The typical storey height in building 1 is 4 000 mm
- The storey height in building 2 is 8 000 mm

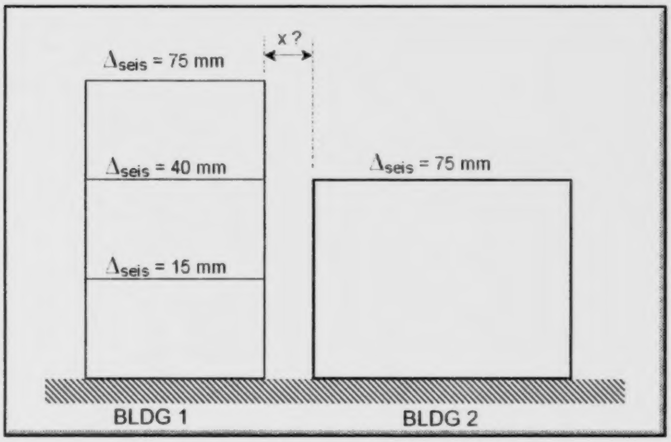
x ?
Δ_{seis} = 75 mm
Δ_{seis} = 40 mm
Δ_{seis} = 75 mm
Δ_{seis} = 15 mm
BLDG 1
BLDG 2

Figure 7-12

Location	Calculated Deflection	Modified Deflection
BLDG 1 Second Floor	15 mm	
BLDG 1 Third Floor	40 mm	
BLDG 1 Roof	75 mm	
BLDG 2 Roof	75 mm	

We know that the deflection refers to the lateral deflection at any point in the structure relative to the ground. Incremental deflection or interstorey deflection refers to the lateral deflection of a storey relative to the one just below it.

Location	Modified Deflection	Interstorey Deflection ($0.025h_s$)	Maximum Lateral Deflection at each Location
BLDG 1 Second Flr			
BLDG 1 Third Flr			
BLDG 1 Roof			
BLDG 2 Roof			

STOP

7.14 DESIGN PROVISIONS

Division B, Article 4.1.8.15. specifies a number of design requirements that are essential for the SFRS and its elements to perform satisfactorily during strong earthquake ground shaking. Although Division B, Section 4.3 gives the overall design provisions for the various structural materials, Article 4.1.8.15. prescribes additional design requirements.

4.1.8.15.(1)
Diaphragms are comprised of some combination of slabs, steel deck, deep beams and trusses. The primary purpose of these diaphragms is to transfer lateral loads to the elements that resist those loads. Although diaphragms are subject to axial, shear and bending actions, their primary action in resisting earthquake loads as part of the SFRS is in shear. In order to ensure that the diaphragm does not yield, it must be designed so that the forces applied to it reflect the strength of the SFRS and that of the elements of the SFRS to which the diaphragm is connected rather than just the computed lateral earthquake loads. However, Division B, Clause 4.1.8.15.(1)(b) specifies that a diaphragm at any level x must be designed for a minimum shear force corresponding to the design base shear, V, divided by the total number of storeys, N.

4.1.8.15.(2)
When the short period spectral design acceleration trigger, $I_EF_aS_a(0.2) \geq 0.35$, elements supporting discontinuous wall, column or braced frames (i.e., Type 4 irregularity) shall be designed for the lateral load capacity of the components of the SFRS that they support.

4.1.8.15.(3)
Where the SFRS of a structure changes at one or more levels, Division B, Sentence 4.1.8.9.(4) specifies the value of the product R_dR_o to be used (i.e., when there is a vertical variation of R_dR_o). Sentence 4.1.8.15.(3) requires that the design forces in the lower SFRS be not less that the capacity of the upper SFRS so as to avoid a weak lower level, which would have the undesirable effect of concentrating all the yielding in the less ductile lower

level.

4.1.8.15.(4)

In many cases, some of the elements of the SFRS will be subject to forces from two loading directions. Take for example an interior column that is common to two orthogonal moment frames that are part of the central core of the structure. Sentence 4.1.8.15.(4) requires that an account be taken for the potential for concurrent yielding of other elements framing into the column or wall from all directions, both at the level under consideration and as appropriate at other levels.

4.1.8.15.(5)

The application of the principals of capacity design to ensure overall ductile behaviour of an SFRS may result in very large element or connection forces due to the large inherent overstrength of some of the connecting elements. Sentence 4.1.8.15.(5) limits the element and connection forces to that determined using the equivalent static force procedure in Article 4.1.8.7., multiplied by the product R_dR_o.

4.1.8.15.(6)

Sentence 4.1.8.15.(6) allows the elements of the SFRS to be designed for maximum values corresponding to the force for which a rocking foundation is designed.

Notes:

STOP

7.15 FOUNDATION PROVISIONS

Earthquakes cause vertical acceleration of the surface of the ground. However, in some cases these accelerations may be too small to cause densification of the soil. Earthquakes also cause horizontal accelerations which give rise to shear stresses. The direction of these shear stresses reverses many times during a strong earthquake as the direction of the acceleration reverses. Conditions in the ground during an earthquake are similar to those in a direct shear test with several reversals of the direction of shearing.

Subsidence of the ground has occurred during large earthquakes. Part of this subsidence is the result of tectonic movement of the underlying rock, but part results from densification of soil. Some of the subsidence during earthquakes is associated with the phenomenon of liquefaction.

When a slope is subjected to an earthquake, the shear stresses associated with ground acceleration will add to the shear stresses required for static equilibrium and may lead to temporary instability of the slope. During large earthquakes there are numerous landslides in natural slopes and slumping of embankments.

Subsection 4.1.8. is primarily concerned with earthquake loads and their effects on the building structure (i.e., usually defined as being above the foundation). It is necessary that the structure and its supporting foundation work integrally in responding to earthquake ground motions, because these ground motions shake the foundation which then transmits the resulting effects to the structural system.

4.1.8.16.(1)
Except where the foundation is allowed to rock, foundations must be designed to resist the lateral load capacity of the SFRS. This will minimize the possibility of the foundation system yielding.

4.1.8.16.(2)
Foundations must be capable of transferring the earthquake loads between the building and the ground without yielding or exceeding the soil resistance capacity (i.e., to prevent degradation of the supporting soil).

4.1.8.16.(3)
Except for low seismic zones (i.e., short period spectral response trigger $I_EF_aS_a(0.2)<0.35$), pile caps must be tied together in two directions. This requirement is intended to inhibit spreading of the piles and subsequent damage to the columns and piles.

4.1.8.16.(4)
Except for low seismic zones (i.e., short period spectral response trigger $I_EF_aS_a(0.2)<0.35$), basement walls must be designed to resist earthquake lateral pressures due to the movement of backfill or natural ground associated with earthquake ground motions.

4.1.8.16.(5)
In high seismic zones (i.e, short period spectral response trigger $I_EF_aS_a(0.2)>0.75$), footings on very soft soils must be tied together. Sentence 4.1.8.16.(4) requires that piles be detailed to accommodate cyclic inelastic behaviour when the moments inducted in the pile by earthquake motions are greater than 75% of the moment resistance of the pile.

4.1.8.16.(6)
Design forces for the ties required by Division B, Clauses 4.1.8.16.(3)(a) or (5)(b) shall be based on the greatest factored pile cap or column vertical load in the element it connects, multiplied by a factor of $0.10\ I_EF_aS_a(0.2)$, applied horizontally in tension or compression.

4.1.8.16.(7)
Loose, saturated soils are prone to liquefaction, which can have serious detrimental effects on a building structure and its foundations. Very large settlements or lateral displacements can take place, which can be very damaging. Sentence 4.1.8.16.(6) requires that sites be reviewed for their potential for liquefaction and that the consequences of liquefaction be accounted for in the

design.

Notes:

STOP

7.16 ELEMENTS OF STRUCTURES, NON-STRUCTURAL COMPONENTS AND EQUIPMENT

Experience during earthquakes has demonstrated the severe consequences of failure or detachment of non-structural building elements/components upon life safety, property damage and economic loss. Non-structural building elements/components include all building components which are not part of the building structure. Examples of these elements/components can be categorized into three divisions; Building Exterior; Building Interior; and Building Contents. Here is a sample list of some of the various components elements that should be considered in this analysis:

Building Exterior

- *Canopies*
- *Overhangs*
- *Porches*
- *Balconies*
- *Parapets*
- *Roof top mechanical units/equipment*
- *Signs*
- *Veneer/cladding*
- *Glazing*

Building Interior

- *Stairs*
- *Stair shafts*
- *Permanent partitions*
- *Doors*
- *Glazing*
- *Light fixtures*
- *Electrical systems (i.e, cables, transformers, generators, etc)*
- *Emergency systems (i.e., fire detector, smoke detector, sprinklers, etc)*
- *Signage*
- *Mechanical equipment (i.e., chillers, heat pumps, furnaces, etc)*
- *Ducts*

Building Contents

- *Demountable partitions*
- *Cabinets*
- *Bookcases*
- *Shelving*
- *Computers*
- *Decorations*
- *Photocopiers*
- *Appliances*

It has been documented that many building structures have survived an earthquake with no structural damage but the facilities are rendered unusable due to extensive non-structural damage.

4.1.8.17.(1)

In order to retain their integrity, attached components need to be designed and detailed so that they do not become detached from the structure when subjected to forces arising from the design level earthquake ground motion. In addition to the design component force specified in Sentence 4.1.8.17.(1), these components need to be able to accommodate the resulting component deflections as well as the earthquake-generated building deflections. Sentence 4.1.8.17.(1) specifies the component design force, V_p, as follows:

$$V_p = 0.3 I_E F_a S_a(0.2) S_p W_p$$

where,

$F_a = \textit{as defined in Division B, Table } 4.1.8.4.B.$

$S_a(0.2) = \textit{as defined in Division B, } 4.1.8.4.(1)$

$I_E = \textit{as defined in } 4.1.8.5.$

$$S_p = \frac{C_p A_r A_x}{R_p}$$

$C_p, A_r, R_p = \textit{component factor from}$ $\textit{Division B, Table } 4.1.8.17.$

$A_x = 1 + \frac{2h_x}{h_n}, (\textit{height factor}), \textit{and}$

$W_p = \textit{weight of the component}$

4.1.8.17.(2)

Components in categories 6 through 21 of Division B, Table 4.1.8.17. are exempt from these requirements if they are in non-post-disaster and the short period spectral response trigger $I_E F_a S_a(0.2) < 0.35$.

4.1.8.17.(4)

Machinery, fixtures, equipment, ducts and tanks containing or not containing toxic or explosive materials (categories 11 and 12 in Table 4.1.8.17.) can be classified as rigid and rigidly connected if the fundamental period of the component and its connection is less than or equal to 0.06 s.

4.1.8.17.(5)

In determining the force V_p for access floors (category 9 in Table 4.1.8.17.), it is necessary to include both the dead load of the access floor itself and the weight of permanent equipment attached to the access floor, which must not be taken as less than 25% of the floor live load.

4.1.8.17.(6)

When heavy tanks are located in buildings, they interact dynamically with the supporting floor system rather than being simply an appendage attached to the floor. In such cases, the lateral forces must be determined by an analysis that considers the tank and the supporting structure as a dynamically coupled system.

4.1.8.17.(7)

In addition to the component gravity loads, the horizontal design force V_p must be applied vertically, either up or down, whichever direction produces the most critical effect for category 6 components (i.e., cantilevered floors, balconies, beams, etc).

4.1.8.17.(8)

Division B, Sentence 4.1.8.17.(8) places additional requirements on the connection details of components to the structure. Clauses 4.1.8.17.(8)(a) through (e) specify the value of R_p that must be used to determine the connection detail design force using the formula in Sentence 4.1.8.17.(1).

4.1.8.17.(9)

Although floors and roofs acting as diaphragms are listed as category 4 in Table 4.1.8.17., no values of the factors C_p, A_r, and R_p are specified. Sentence 4.1.8.17.(9) requires that these structural components meet the requirements of Article 4.1.8.15.

4.1.8.17.(10)

When an elastic analysis is used for determining lateral deflections of components, the computed deflections must be multiplied by R_p/I_E.

4.1.8.17.(11)

When components are rigid walls or panels, the requirements of Clause 4.1.8.3.(6)(b) must be satisfied (i.e., such components must be made part of the SFRS if there is insufficient separation to preclude interaction with the structure).

4.1.8.17.(12)

Sentence 4.1.8.17.(12) requires seismic restraints, such as sway bracing used to restrict the lateral motion of suspended components, to be located so that they do not impose bending on the hanger rods used to suspend the equipment.

4.1.8.17.(13)

Isolated suspended components, such as pendant lights, may be designed as a pendulum system provided that the supporting chains or rods are designed to support twice the weight of the suspended component and the deflection requirements of Sentence 4.1.8.17.(10) are satisfied.

EXERCISE № 7-10

Consider the following building description for all questions in this exercise:

- The building is 9 storeys in building height
- All floors are residential condominium units
- The site is located in Ottawa, Ontario
- The site classification is D
- The base of the building is at grade
- Each storey, including the top storey measures 3.5 m from top of floor to top of floor (i.e., for top storey it is measured to top of roof).

1. Suspended ceilings are located 2.8 m above the floor on all storeys in the public corridors. Determine the design lateral force for the suspended ceiling on the 9th storey, the 6th storey and the ground floor. For every 1 m of length by width of corridor, the suspended ceiling weighs 2.4 kN.

Location	h_x	h_n	$A_x = 1 + 2h_x/h_n$
9th			
6th			
Ground			

Location	W_p	S_p	V_p
9th			
6th			
Ground			

2. Determine the lateral force on a flexible liquid tank, with 0.5 m high support legs and a centroid of 1.5 m above the floor, located on the roof of the building. The tank weighs 15 kN empty and 100 kN when filled with diesel fuel.

STOP

MODULE 8

OTHER STRUCTURAL LOADS AND SPECIAL STRUCTURES

BUILDING STRUCTURAL – 2006

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8.0 INTRODUCTION

In this Module, participants will learn about the minimum loading and structural requirements, other than those already discussed in Modules 3 to 7, for the design of *building* structures and designated structures using Part 4 of the Building Code.

8.1 OBJECTIVES

Upon completion of this Module participants will be able to:

- Find and understand the structural requirements located in Division B, Part 3
- Recognize the requirements for the prevention of *firewall* and *fire separation* collapse
- Identify the difference between grab-bars, handrails and *guards*, and be able to determine the structural design loading requirements for each
- Determine the requirements for window protection in apartment *buildings*
- Find the Code requirements for fixed access ladders
- Characterize impact loads and the requirements for crane-supporting structures
- Relate the Code provisions for anchor systems and special structures including parking structures and air-supported structures

8.2 FIREWALL AND FIRE SEPARATION COLLAPSE PREVENTION

With reference to Division A, Article 1.4.1.2, the following are defined terms, necessary to understand the Code requirements for prevention of *firewall* and *fire separation* collapse:

- ***Fire separation*** means a construction assembly that acts as a barrier against the spread of fire.
- ***Firewall*** means a type of *fire separation* of *noncombustible construction* that subdivides a *building* or separates adjoining *buildings* to resist the spread of fire and that has a *fire-resistance rating* as prescribed in this Code and has structural stability to remain intact under fire conditions for the required fire-rated time.
- ***Noncombustible*** means that a material meets the acceptance criteria of CAN4-S114, "Standard Method of Test for Determination of Non-Combustibility in Building Materials".
- ***Combustible*** means that a material fails to meet the acceptance criteria of CAN4-S114, "Standard Method of Test for Determination of Non-Combustibility in Building Materials."
- ***Noncombustible construction*** means a type of construction in which a degree of fire safety is attained by the use of *noncombustible* materials for structural members and other building assemblies.
- ***Combustible construction*** means a type of construction that does not meet the requirements for *noncombustible construction*.
- ***Fire-resistance rating*** means the time in minutes or hours that a material or assembly of materials will withstand the passage of flame and the transmission of heat when exposed to fire under specified conditions of test and performance criteria, or as determined by extension or interpretation of information derived from that test and performance as prescribed in this Code.

In reading these definitions, it is important to understand a *fire separation* wall is a wall between two spaces that is meant to stop or slow the spread of fire, while a *firewall* is a fire separation that must remain standing after one side of the *building* has collapsed.

In *buildings*, it is common for *firewalls* and *fire-separations* to act as *loadbearing* elements that support floor or roof framing elements, however such walls may also be non-*loadbearing*. If a firewall relies on support from other elements, those elements require the same fire resistance rating as the firewall.

The applicable Code requirements for *buildings* designed using Part 4 are found in OBC 3.1.8.2 and OBC 3.1.10.1. Corresponding requirements for Part 9 buildings are given in Article 9.10.9.8.

The structural provisions for *firewalls* are found in Article 4.1.5.18, which form part of the Subsection that deals with *live loads* due to use and *occupancy*.

Commentary C of the "User's Guide – National Building Code 2005 Structural Commentaries (Part 4 of Division B)" provides guidance on the design of *firewalls* for structural integrity. Note that the content of the User's Guide does not form part of the examination syllabus.

Exercise #8-1

With reference to Article 3.1.8.2 and Article 3.1.10.1, complete the following exercise. Then discuss your answers with your group.

1. Is the following statement true or false?
   "A *firewall* is a type of *fire separation*, therefore the requirements of Article 3.1.8.2 with respect to collapse prevention also apply to *firewalls*."

   ☐ True ☐ False

   OBC Reference(s): ____________________

2. In Figure 8:1, a series of wood joists are supported from a *loadbearing* masonry *firewall*. The joists are constructed with sloped ends allowing to them rotate as shown, in the case of a fire. The wall's unbraced height is such that it does not rely upon the wood joists to provide lateral support.
   Does this design comply with the Code?

   ☐ Yes ☐ No

   Why? ____________________________

   ____

OBC Reference(s): ______________________

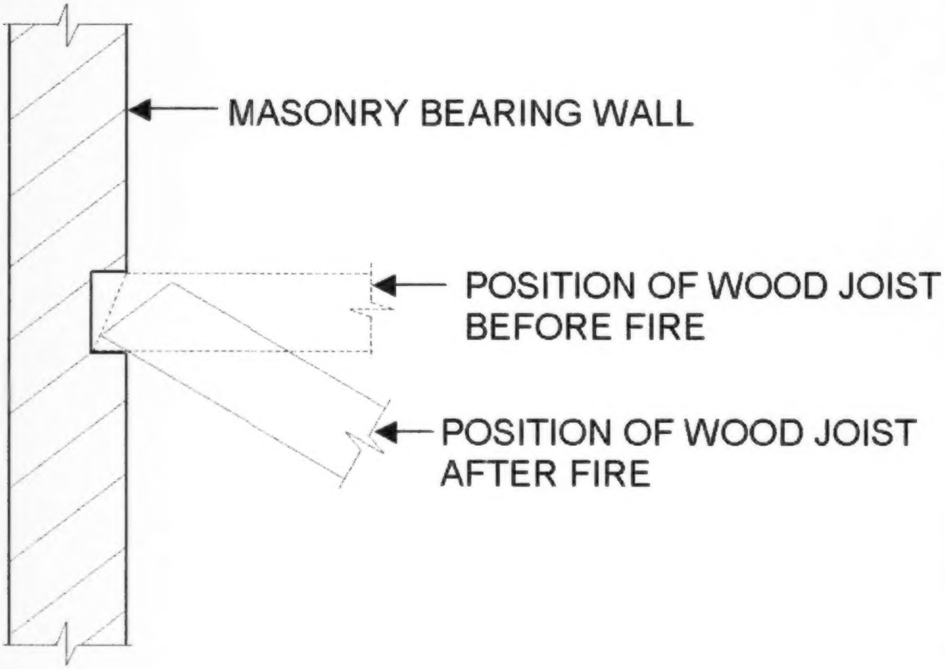
MASONRY BEARING WALL
POSITION OF WOOD JOIST BEFORE FIRE
POSITION OF WOOD JOIST AFTER FIRE

Figure 8:1

Joist/Wall Connection (Exercise #8-1)

3. If the masonry *firewall* in Figure 8:1 is required to have a *fire-resistance rating* of 2 hours, and the wall is supported on a steel beam, which of the following statements would be true?

   a) Beam must have a *fire-resistance rating* of at least 3.0 hours

   b) Beam must have a *fire-resistance rating* of at least 2.0 hours

   c) Pipes and conduits are not allowed to pass through the wall

   d) *Combustible* construction may not be supported on a masonry *firewall*

OBC Reference(s): ________________

4. If the masonry wall in question 3, above, is supported on a wood beam, what measures would need to be taken to comply with the Code?

   ____

   ____

OBC Reference(s): ________________

Exercise #8-2

Read Article 4.1.5.18 of Division B.
Complete the following exercise, then discuss the answers with your group.

1. What is the minimum lateral load to be used in the design of an interior *firewall*?

   a) 0.5 kPa factored load

   b) Wind loads determined using Article 4.1.7.4

   c) Earthquake loads determined using Article 4.1.8.17

   d) a), b) or c), whichever produces the greatest effect

   OBC Reference(s): ________________

2. What is the minimum *fire-resistance rating* required for a floor system that is relied upon to provide lateral support for a 2-hour *firewall*?

   a) 45 minutes

   b) 1 hour

   c) 2 hours

   d) 3 hours

   OBC Reference(s): ________________

STOP

8.3 DESIGN LOADS AND REQUIREMENTS FOR HANDRAILS

A handrail is a horizontal or sloping rail intended for grasping by the hand for guidance and/or support. Handrails are provided to help support a person requiring something to hold on to as they use steps or a ramp. Handrail requirements are found in both Part 3 and Part 9 of Division B of the Building Code.

Exercise #8-3

Read Article 3.4.6.1.
Complete the following exercise, then discuss the answers with your group.

1. For handrails located in *exits*, what is the minimum specified design load to be used for the design of the handrails and their anchorages and supports? (Assume that the handrail does not also serve as a *guard*.)

   a) 0.7 kN/m, acting in any direction, along the length of the handrail

   b) 0.9 kN concentrated load, acting in any direction, located such as to produce the maximum effects on any part of the handrail

   c) a) and b) as separate load cases

   d) a) and b) acting together

   OBC Reference(s) ______________

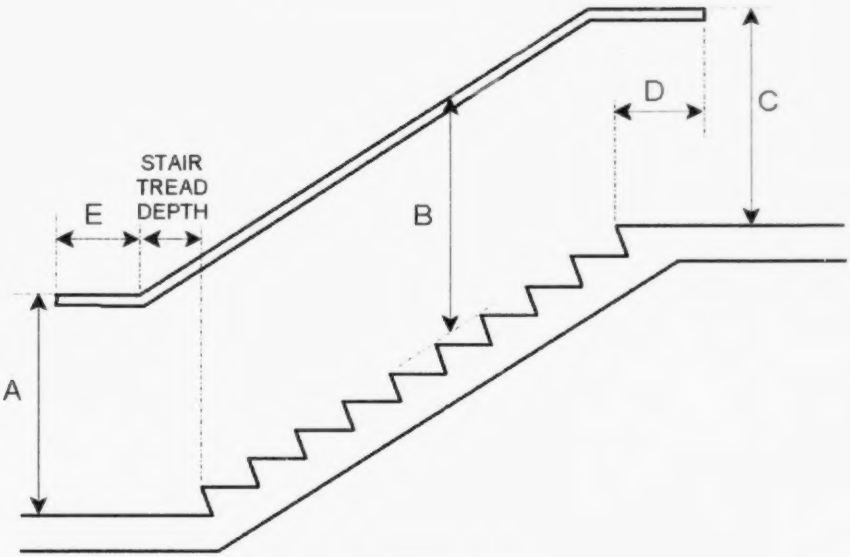

FIGURE 8:2

Handrails (Exercise #8-3)

2. With reference to Figure 8:2, which of the following statements are false?
   a) Dimensions A, B and C must be between 865 mm and 965 mm
   b) If the stair is 1000 mm wide, and is in a nursing home, then one handrail on each side of the stair is required
   c) Dimensions D and E must be at least 300 mm
   d) The handrail may be constructed of 38 mm x 89 mm (2 x 4) wood or aluminum

OBC Reference(s) ______________

STOP

8.4 FIXED ACCESS LADDERS

Fixed access ladders which are poorly secured to the structure they serve may pull away from the structure and cause death or serious injury to persons using them. Inadequately designed ladders may not be able to support the required loads.

Article 3.6.1.5 requires the design and installation of fixed access ladders to be in accordance with the Supplementary Standard SB-8 "Design, Construction and Installation of Anchorage Systems for Fixed Access Ladders".

Exercise #8-4

Read Sentence 3.6.1.5.(1) and Supplementary Standard SB-8. Complete the following exercise, then discuss the answers with your group.

1. For the fixed access ladder shown in Figure 8:3 (below), what is the maximum allowable dimension "A"?
   a) 900 mm
   b) 2400 mm
   c) 3000 mm
   d) 5000 mm

2. What is the minimum design *live load* for a fixed access ladder?
    - a) 1 load 1.1 kN on each rung
    - b) 2 loads of 1.1 kN on each rung
    - c) 1 load of 1.1 kN on any points between consecutive attachments
    - d) 2 loads of 1.1 kN on any points between consecutive attachments

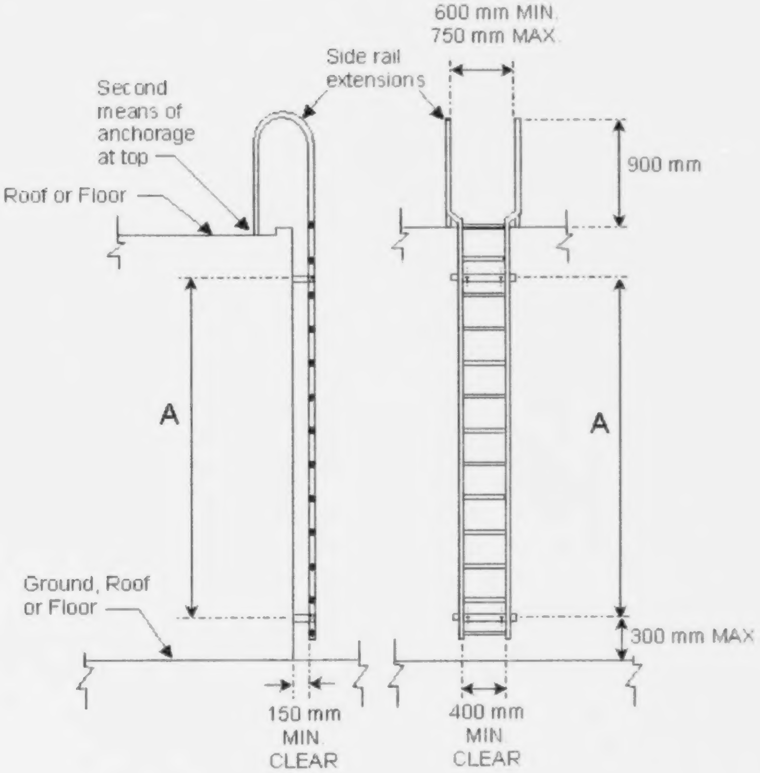
600 mm MIN.
750 mm MAX.
Side rail extensions
Second means of anchorage at top
Roof or Floor
900 mm
A
A
Ground, Roof or Floor
300 mm MAX
150 mm MIN. CLEAR
400 mm MIN CLEAR

Figure 8:3
Fixed Access Ladder (Exercise #8-4)

3. For a fixed access ladder (not supporting a fall-arrest system), what is the minimum factor of safety to be applied to the pull-out rating of a manufactured expansion anchor used to connect the ladder to a concrete wall?

   a) 1

   b) 4

   c) 10

   d) Through-bolts must be used to connect the ladder to the wall.

4. If a fixed access ladder is to be installed on an existing wall, what are the Code requirements for the existing wall?

   a) The structural soundness of the wall must be investigated, and the wall must be reinforced if necessary

   b) The wall must be reinforced to support the additional ladder loads

   c) A safety factor of 10 is required, even if the ladder does not form part of a fall-arrest system

   d) There are no specific Code requirements

STOP

8.5 DESIGN LOADS FOR GRAB BARS

A grab bar is a safety bar installed in a bathtub or shower for use when bathing, or any bar attached parallel to a wall to provide a handgrip to steady one's self. Section 3.8 Barrier-free Design has specific requirements for the configuration and location of grab bars.

Figure 8:4
Grab Bar

Exercise #8-5

Read Article 3.7.4.14. Complete the following exercise, then discuss the answers with your group.

1. Which of the following should be used as the specified design load for grab bars, their anchorages, and supports?
   a) 1.3 kN concentrated load, acting vertically, located such as the produce the maximum
   b) 1.3 kN concentrated load, acting horizontally, located such as the produce the maximum
   c) a) and b) as separate load cases
   d) a) and b) acting together

STOP

8.6 WINDOW PROTECTION IN APARTMENT BUILDINGS (PART 3 BUILDINGS)

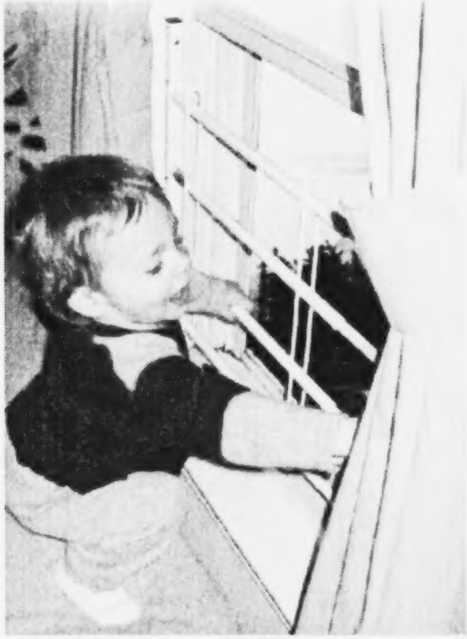

Figure 8:5
Window Guard
(photo credit: Safe Beginnings Inc.)

Exercise #8-6

Read Article 3.7.2.2. Complete the following exercise, then discuss the answers with your group.

1. Is the following statement true or false?

   "Window *guards* are not required on windows that have heavy-duty screens conforming to CSA-A440 and stops that prevent them from opening more than 100 mm."

   ☐ True ☐ False

OBC Reference(s): ____________________

2. Is the following statement true or false?

   "Window *guards* or equivalent alternate means of fall protection are only required in *dwelling units* above the 3rd floor of Group C *major occupancy* apartment *buildings*."

   ☐ True ☐ False

OBC Reference(s): ____________________

3. Is the following statement true or false?

   "Window *guards* or equivalent alternate means of fall protection are not required for windows located more than 1500 mm above floor level."

   ☐ True ☐ False

OBC Reference(s): ____________________

4. Is the following statement true or false?

   "Window *guards* or equivalent alternate means of fall protection are not required for windows in *dwelling units* where a balcony (that complies with the Code) is located in front of the window."

   ☐ True ☐ False

OBC Reference(s): ______________

5. For the following statement, fill in the blanks:

"A fixed window must be designed to resist the loads of Part 4, for balcony *guards*, when all of the following conditions exist":

a) Group C major occupancy _________ *building*

b) Window is within a _______ *unit*

c) Base of fixed window is less than _____ mm above floor level

d) Fixed window is not otherwise protected by a _____ that extends at least _____ mm above floor level

e) An exterior _______ is not constructed for the full length of the _______.

OBC Reference(s): ________________

____

____

STOP

8.7 GUARDS

Guards are protective barriers intended to prevent accidental falls. The formal Code definition for *guard* is given in Division A, Article 1.4.1.2.

Part 3 precribes the locations in a *building* where *guards* are required, and the required dimensions for *guards*. Additionally, Subsection 4.4.3 is applicable to retaining walls designated under 1.1.3.1 Division A.

The Code requirements for structural loading on *guards* are given in Articles 4.1.5.15 to 4.1.5.17. Note that these are considered *live loads* due to use and *occupancy*.

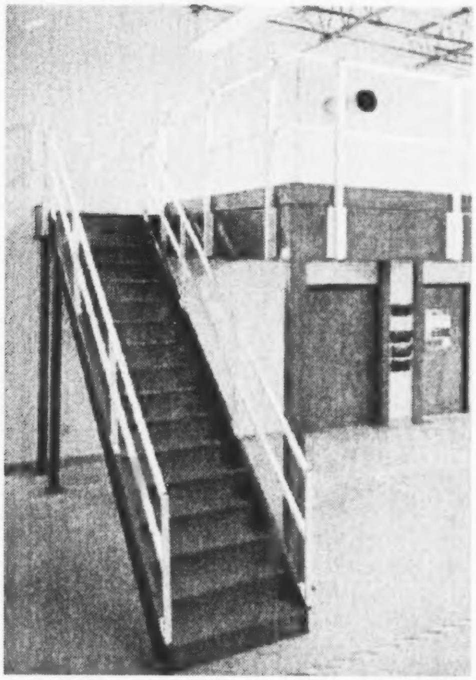

Figure 8:6
Guards at Mezzanine and Open Stairs (Exercise #8-7)

Exercise #8-7

Read Articles 4.1.5.15 to 4.1.5.17, and Article 4.4.3.1. Complete the following exercise, then discuss the answers with your group.

1. In Figure 8:6, the handrails on the stair also serve as *guards*. Which of the following give the structural loading requirements for the stair handrails?
   a) Article 3.4.6.4
   b) Article 4.1.5.15
   c) Both a) and b), acting together
   d) a) or b), whichever produces the greatest effect

   OBC Reference(s): ________________

2. In a residential apartment *building*, what are the required design loads for a balcony *guard*?

   a) ________ kN/m horizontal, at top

   b) ________ kN/m vertical, at top

   c) ________ kN horizontal, at top

   d) ________ kN concentrated on 100 mm x 100 mm, at any point

OBC Reference(s): ______________

3. Consider a non-*loadbearing* wall that encloses an interior stair, and acts as a *guard* to prevent accidental falls from the occupied floor levels into the stair.
   What is the minimum specified out-of-plane lateral design *live load* for the wall?

   a) 0.5 kPa

   b) wind loads and earthquake loads determined using the provisions of Part 4

   c) *guard* loads given in Article 4.1.5.15

   d) a), b) or c), whichever produces the greatest effect

OBC Reference(s): ______________

4. What is the minimum horizontal load to be considered in the design of the *guard* at the edge of an above-grade parking garage?

   a) 22 kN at 500 mm above the floor

   b) 1.0 kN at any point

   c) 0.75 kN/m at the top of the guard

   d) all of the above

OBC Reference(s): ______________

STOP

8.8 CRANE-SUPPORTING STRUCTURES AND IMPACT OF MACHINERY AND EQUIPMENT

Article 4.1.5.12 provides the structural loading requirements for crane supporting structures, and the impact loads due to equipment and machinery.

Exercise #8-8

Read Article 4.1.5.12. Complete the following exercise, then discuss your answers with your group.

1. The double girder crane in Figure 8:7 has a maximum lifting capacity of 20 tons (180 kN). The self-weight of the crane assembly is 20 kN. The load is shared equally between the two support girders. If the crane is hand-operated, what is the maximum specified vertical design load to be applied to each girder?
    - a) 100 kN
    - b) 110 kN
    - c) 200 kN
    - d) 220 kN

OBC Reference(s): ________________

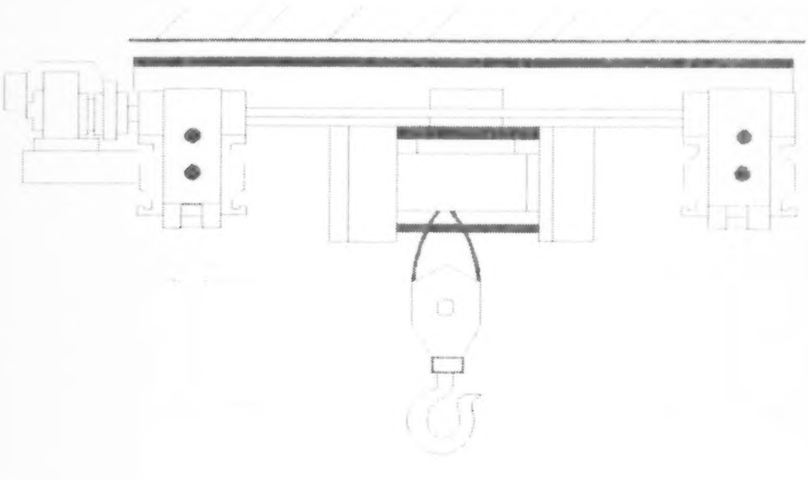

Figure 8:7
Double Girder Crane (Exercise #8-8)

2. For the crane system in question 1 above, what is the minimum transverse horizontal design load that must be applied to the top of each girder?
   a) 20 kN
   b) 24 kN
   c) 40 kN
   d) 48 kN

OBC Reference(s): ______________

3. For the crane system in question 1 above, what is the minimum longitudinal horizontal design load that must be applied to the top of each girder? For this question, assume that the lifting hook may be positioned directly under either girder.
   a) 10 kN
   b) 12 kN
   c) 20 kN
   d) 24 kN

OBC Reference(s): ______________

4. For which of the following is it not a Code requirement to consider the effects of impact when determining *live loading*?
   a) Side rails in elevator shafts
   b) Inertia base foundation for motorized equipment
   c) Guards on balconies
   d) Crane supporting structure

OBC Reference(s): ______________

STOP

8.9 SPECIAL STRUCTURES

Section 4.4 of the Code contains provisions and requirements for special structures, including air-supported structures, parking structures, guards over retaining walls, anchor systems on building exteriors, and manure storage tanks.

The following exercise will review the requirements for these special structures, with the exception of manure tanks, which are discussed in Module 19.

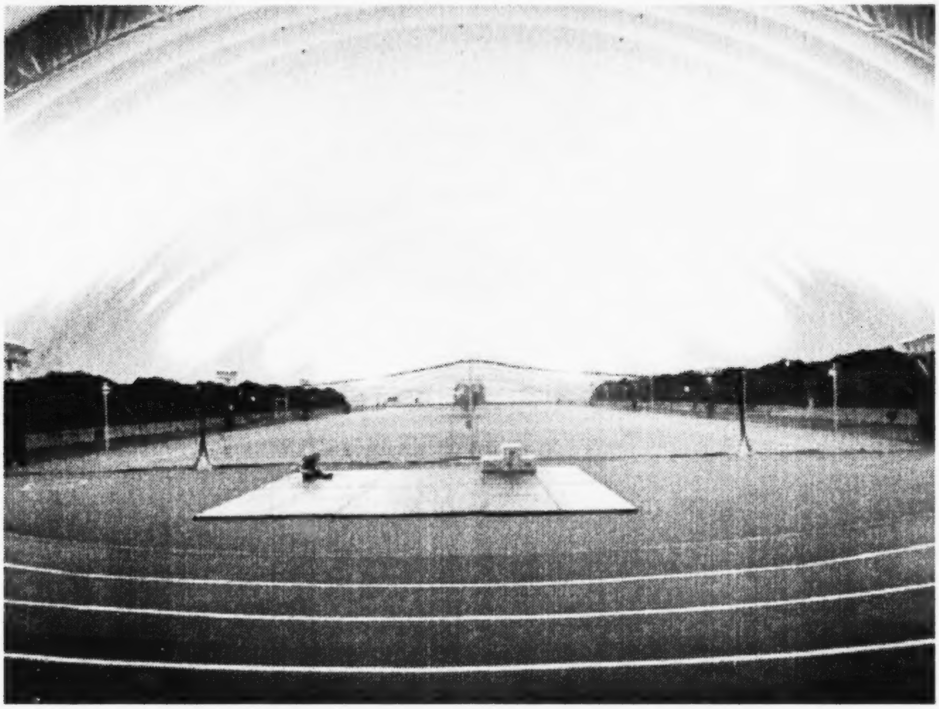

Figure 8:8
Air-Supported Structure
(photo credit: The Farley Group)

Exercise #8-9

Read Section 4.4, excluding Subsection 4.4.5.
Complete the following exercise, then discuss the answers with your group.

1. Which of the following contains the specified structural requirements for the design of air-supported structures?

   a) ASTM E108

   b) CAN4-S109

   c) CAN3-S367

   d) NFPA 701

OBC Reference(s): ________________

2. With respect to Code requirements for anchor systems on *buildings*, which of the following statements is false?

   a) Design of anchorage systems shall be in accordance with CSA Standard Z91, or a method that provides an equivalent level of safety

   b) Anchors are only required if the *building* has windows

   c) Anchorage systems must be corrosion-resistant

   d) Anchors are required where the elevation difference between the roof and ground exceeds 8 m, and where exterior maintenance and window cleaning is carried out

OBC Reference(s): ________________

3. To which of the following does the requirements of CAN/CSA-S413 apply?

   a) Guards on retaining wall

   b) Roof anchors

   c) Parking garage

   d) Manure storage tank

OBC Reference(s): ________________

4. True or false:

   "*Guards* are required on open sides of retaining walls, designated in Sentence 1.3.1.1.(1) of Division A, where the public has access to the top of the wall."

   ☐ True ☐ False

   OBC Reference(s): ________________

STOP End of Module 8

MODULE 9

FOUNDATIONS DESIGNED USING PART 4

BUILDING STRUCTURAL – 2006

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9.0 INTRODUCTION

In this Module, participants will learn about the Code requirements for *foundations* and *excavations*, for *buildings* designed and constructed using Part 4 of the Building Code.

9.1 OBJECTIVES

Upon completion of this Module, participants will:

- Identify the information required/provided in a subsurface investigation report
- Find information on the allowable bearing capacity for soil
- Identify the role of field review and inspection during construction
- Explain the different types of *foundation* systems
- Find the requirements for selection of construction materials
- Deal with unforeseen soil conditions and incorrect alignment, incorrect location and damage to *foundations* during construction
- Recognize the importance of design of *excavations* and backfilling, including dewatering

9.2 SUBSURFACE INVESTIGATIONS

Article 4.2.2.1 requires that for all *buildings* and *excavations* designed under Part 4, a *subsurface investigation* be carried out, and identifies the persons authorized to carry out such investigations.

The Code provides the following definition:

> *Subsurface investigation* means the appraisal of the general subsurface conditions at a *building* site by analysis of information gained by methods such as geological surveys, in situ testing, sampling, visual inspection, laboratory testing of samples of the subsurface materials and *groundwater* observations and measurements.

The *subsurface investigation* is essential to the design and construction of a *building*, as it provides basic site-specific information to the structural *designer* and contractor.

The structural *designer* should work closely with the geotechnical engineer during the *subsurface investigation*, so that information on expected *building* configuration, location and *Foundation* loads can be accounted for in the *subsurface investigation* report.

Exercise #9-1

Read Article 4.2.2.1, Sentence 4.2.4.1.(1) and Articles 4.2.4.2 and 4.2.4.3.
Complete the following exercise, then discuss your answers with your group.

1. According to the Building Code, which of the following must be identified and classified, and have their engineering properties determined, as part of a *subsurface investigation*?
   a) *soil*
   b) *rock*
   c) *groundwater*
   d) all of the above

OBC Reference(s): ____________________

2. In a *subsurface investigation*, what is the required depth of *soil* sampling/testing?
   - a) Below the level of potential damage due to *frost action*
   - b) Below the level of *groundwater*
   - c) To such a depth as to evaluate potential changes in stress caused by the *building*, and to provide all the necessary information for design and construction
   - d) As directed by the Chief Building Official.

OBC Reference(s): ____________________

3. A *subsurface investigation* report indicates an *allowable bearing pressure* for a dense sand to be 200 kPa. What value of *allowable bearing pressure* should be used for the design of *shallow foundations*, using the provisions of Part 4?
   - a) 150 kPa, per Division B, Table 9.4.4.1
   - b) 200 kPa, per the *subsurface investigation*
   - c) Either 150 kPa or 200 kPa, as directed by the Chief Building Official
   - d) None of the above

OBC Reference(s): ____________________

4. According to the Code, who is allowed to carry out a *subsurface investigation*?

____

____

____

OBC Reference(s): ____________________

STOP

9.3 MATERIALS USED IN FOUNDATIONS

Subsection 4.2.3 specifies the requirements for the materials used in *foundations*. The provisions of Subsection 4.2.3 are additional to those of Section 4.3, and have specific requirements pertaining to durability.

EXERCISE #9-2

Read Subsection 4.2.3 and complete the following exercise. Then discuss your answers with your group.

1. According to the Building Code, what portions of wood used in *foundations* must be treated with preservatives to prevent deterioration?
   - a) Wood located above the lowest anticipated *groundwater* table, exposed to soil
   - b) Wood located above the highest anticipated *groundwater* table, exposed to soil or air
   - c) Wood located above the lowest anticipated *groundwater* table, exposed to soil or air
   - d) All wood *foundations*

OBC Reference(s): ____________________

2. Which of the following reference standards do not address the material requirements for steel *piles*?
   - a) ASTM-A252
   - b) CAN/CSA-A23.1-M
   - c) ASTM-A1011/1011M
   - d) CAN/CSA-G40.21-M

OBC Reference(s): ____________________

3. According to Subsection 4.2.3, what elements of *foundation* systems are governed by CSA Standard A23.1?

   a) ______________________________________

   ____

   b) ______________________________________

   ____

OBC Reference(s): ____________________

4. What is the reference standard that governs the material requirements for concrete unit masonry *foundation* piers?

   a) CSA Standard A23.1

   b) CSA Standard S304

   c) CSA Standard S304.1

   d) Any of the above

OBC Reference(s): ____________________

5. For which of the following materials does Subsection 4.2.3 address the prevention of deterioration, when the material is used in a *foundation*?

   a) Masonry

   b) Concrete

   c) Steel

   d) All Of The Above

OBC Reference(s): ____________________

STOP

9.4 EXCAVATIONS AND BACKFILLING

In the construction of most *buildings*, *excavations* may be required before the structure can be built. Since *excavations* represent a significant danger to lives and to adjacent properties, the Code requires that *excavations* be designed.

Excavations may have sloped sides, or may be supported by temporary earth retaining systems. The maximum allowable slope of an unbraced excavation is often called the "angle of repose", and is determined by specialized geotechnical analysis and/or testing.

The Code requires that *excavations* within the angle of repose of the soil must be designed by a *Professional Engineer* as stated in Division C, Sentence 1.2.1.1.(5) and Clause 1.2.2.3.(1)(c).

Often, *excavations* with vertical sides are necessary, such as in urban areas where *excavations* extend to property lines. In these cases, it is necessary to provide protection to adjacent properties where collapse of the *excavation* might cause loss of bearing capacity, settlement or lateral movement to existing property. Vertical excavations normally require the use of an earth retaining systems (also known as "shoring").

The type of earth retaining system to be used for any particular *building* project depends on the requirements and conditions of the project, and the expertise and preferred methods of the contractors at the project location.

The design of *excavations* and shoring is normally carried out by specialist *Professional Engineers*.

Subsection 4.2.5 contains the Building Code requirements for *excavations* and for backfilling.

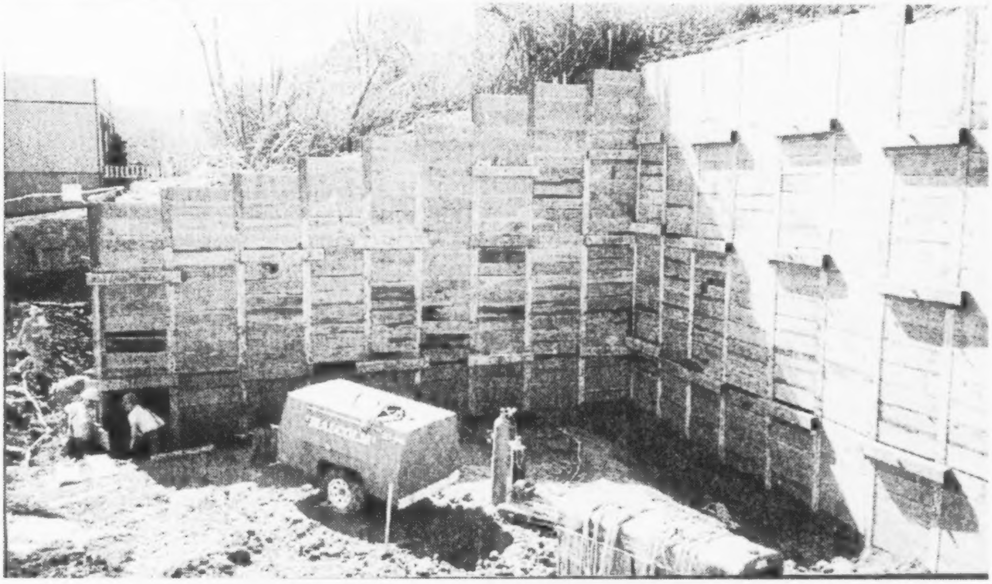


Figure 9:1
Supported Excavation With Tiebacks - Articles 4.2.5.3 and 4.2.3.9

Exercise #9-3

Read Subsection 4.2.5 of Division B and Sentence 1.2.1.1.(5) of Division C. Complete the following exercise, then discuss your answers with your group.

1. What are the Code Sentences that govern the design of *excavations*?
   a) ______________________________
   b) ______________________________
   c) ______________________________
   d) ______________________________
2. Which of the following must be controlled when making an *excavation*?
   a) *Groundwater*
   b) *Perched groundwater*
   c) *Artesian groundwater*
   d) All of the above

OBC Reference(s): ________________________

3. When is it permissible to make an *excavation* without the use of an earth retaining system?

   a) When the slope of the cut is less than the angle of repose

   b) When the *building* is less than 11 m high, and has $I_EF_aS_a(0.2)$ less than 0.35

   c) When *excavation* is designed by an especially qualified person

   d) When the *excavation* is designed by a *Professional Engineer*

OBC Reference(s): ____________________

4. List the items that must be protected in the design and construction of *excavations*:

   a) ____________________

   b) ____________________

   c) ____________________

OBC Reference(s): ____________________

5. List the factors that may cause deterioration of *excavations*:

   a) ____________________
   b) ____________________
   c) ____________________
   d) ____________________
   e) ____________________

OBC Reference(s): ____________________

6. Which of the following is not a required consideration in the backfilling of *excavations*?
   a) Degree of inspection
   b) Lateral support of soil adjacent to the *excavation*
   c) Prevention of detrimental movements
   d) Use of materials not subject to detrimental volume change

   OBC Reference(s): ______________

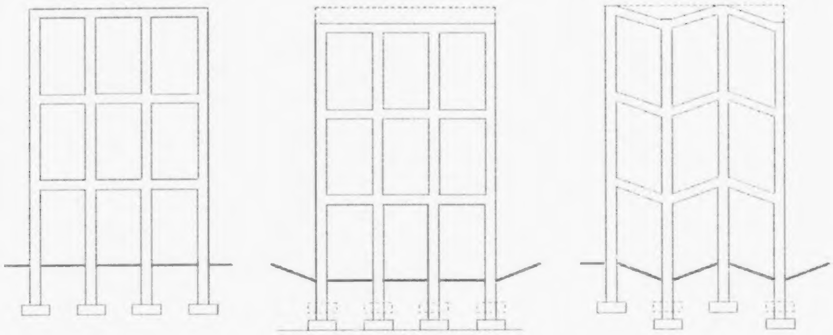
STOP

9.5 DESIGN OF FOUNDATIONS

Subsection 4.2.4 states the Code provisions governing the design of *foundations*.

The basic steps in the design of *foundations* involves:

- Calculating the loads on the *foundation* - Sentence 4.2.4.1.(2).
- Determining the character of subsurface *soil* and *groundwater conditions* - Articles 4.2.2.1 and 4.2.4.2
- Determining the engineering properties of the supporting *soil* or *rock* – Sentences 4.2.4.1.(3) and (4)
- Designing a *foundation* that will safely transfer the loads from the structure to *soil* and *rock* at the site – Sentences 4.2.4.1.(2) and (5)



NO SETTLEMENT

TOTAL SETTLEMENT

DIFFERENTIAL SETTLEMENT

Figure 9:2
Example of Settlements – Sentence 4.2.4.1.(5)

Exercise #9-4

Read Subsection 4.2.4 and complete the following exercise. Then discuss your answers with your group.

1. Notwithstanding the requirements of Division C, Article 1.2.1.1, which of the following persons is allowed by the Code to carry out design of *foundations*, *excavations* and earth-retaining structures?
    a) *Professional engineer*
    b) General contractor
    c) Person competent in this field
    d) Geotechnical engineer

OBC Reference(s): ____________________

2. The term permafrost refers to the condition of earth materials under which their temperature remains below 0°C continuously for a number of years. If a *building* is to be constructed on permafrost, which of the following persons is allowed by the Code to carry out design of *foundations*, notwithstanding the requirements of Division C?

   a) *Professional engineer*

   b) Person especially qualified in this field

   c) Person competent in this field

   d) Geotechnical engineer

   OBC Reference(s): ____________________

3. What is the reference standard to be used for the structural design of a reinforced concrete footing?

   a) CSA Standard A23.1

   b) CSA Standard A23.2

   c) CSA Standard A23.3

   d) None of the above

   OBC Reference(s): ____________________

4. Which of the following is not an acceptable basis for the design of *foundations*?

   a) Load testing by a competent person

   b) Calculations applying engineering principles

   c) Trial and error methods

   d) Use of the same *foundations* as those used successfully on a nearby similar *building* on similar *soil*, using similar construction methods

OBC Reference(s): ____________________

5. Which of the following are Code requirements for the design of *foundations* and *excavations*?

   a) Consideration of ultimate limit states, using factored loads

   b) Consideration of serviceability limit states, using unfactored loads

   c) Communication between the persons responsible for the *subsurface investigation* and the persons responsible for the structural design

   d) All of the above

OBC Reference(s): ____________________

6. A *subsurface investigation* report indicates that competent *soil* with adequate properties exists at a depth of 500 mm below existing *grade*, but that the *soil* is frost-susceptible with a required depth of frost protection of 1200 mm. If a proposed *building* is to be unheated, what the minimum depth of interior footings?

   a) 500 mm, measured from the top of the footing to new or existing grade

   b) 500 mm, measured from the bottom of the footing to new or existing grade

   c) 1200 mm, measured from the top of the footing to new or existing grade

   d) 1200 mm, measured from the bottom of the footing to new or existing grade

OBC Reference(s): ____________________

7. Which of the following are not mandatory requirements for the construction of a *building foundation* on soil consisting of *fill*?

   a) Potential movements have been considered in the design, and the movements have been shown not to be detrimental

   b) The design has accounted for the effects of explosive gases, or a *subsurface investigation* has determined that such gases do not occur

   c) Additional inspection by a *Professional Engineer* is carried out during construction

   d) Measures have been taken to ensure that the *building* can be safely supported

OBC Reference(s): ____________________

8. List the special situations where Subsection 4.2.4 requires that special provisions be made in the design.

	Situation	Code Reference
a)		Sentence 4.2.4.5.(1)
b)		Sentence 4.2.4.6.(1)
c)		Sentence 4.2.4.7.(1)
d)		Sentence 4.2.4.8.(1)
e)		Sentence 4.2.4.9.(1)
f)		Sentence 4.2.4.10.(1)
g)		Sentence 4.2.4.11.(1)
h)		Sentence 4.2.4.12.(1)

STOP

9.6 TYPES OF FOUNDATION SYSTEMS

The purposes of *foundations* for *buildings* are to safely transfer structural loads to the supporting *soil* or *rock*, within necessary strength (ULS) and deformation (SLS) limitations. In general, *foundations* may be classified as either "shallow" or deep".

Shallow foundations:

- Includes spread footings, wall or strip footings, and mat or raft *foundations*
- In general, *shallow foundations* have a depth of less than about 3 metres or less than the width of the *foundation unit*

Deep foundations:

- Includes *piles* and caissons, typically where the depth of the *foundation units* are larger than about 4 times their width or diameter
- *Deep foundations* may be used singly or in groups

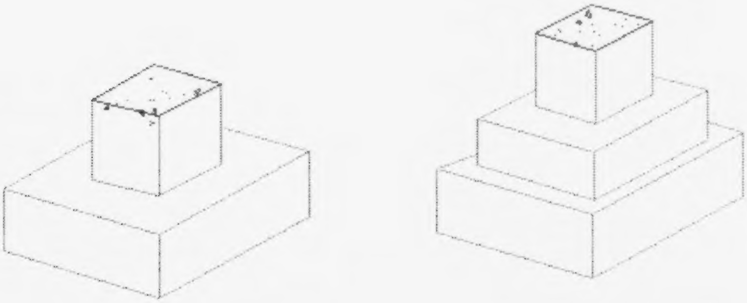
Selection of the type of *foundation* system depends on the interaction between the structure and the supporting *soil* and *rock*. The strength and deformation properties of *soil* depends on the shape and loading of the *foundation units*, therefore different *buildings* on similar *soil* strata may require completely different *foundation* systems.

A typical *subsurface investigation* report will provide recommendations to the *designer* with respect to the selection of an appropriate *foundation* system.

9.6.1 Shallow Foundations

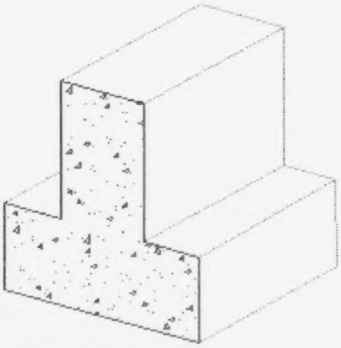
Shallow foundations may consist of spread footings supporting isolated columns, combined footings for supporting loads from several columns, strip footings for supporting walls, and mats for supporting the entire structure. *Shallow foundations* tend to be used wherever possible, for reasons of cost, provided *adequate bearing pressure* of the *soil* or *rock* is available near ground surface, and the conditions for settlement/expansion of underlying *soil/rock* is acceptable.

The Building Code requirements for *shallow foundations* are given in Subsection 4.2.6.



SIMPLE COLUMN FOOTING

COLUMN WITH PIER



SIMPLE WALL FOOTING

Figure 9:3
Shallow Foundations – Example Footing Types – Article 4.2.6

EXERCISE #9-5

With reference to Subsection 4.2.6, complete the following exercise. Then discuss your answers with your group.

1. Which of the following are not mandatory considerations in the design and construction of *shallow foundations*?
   - a) *Soil* or *rock* must be adequate to support the design load
   - b) Construction methods that may affect *soil* properties during construction
   - c) Temperature and precipitation that may affect *soil* properties
   - d) Frequency and type of inspection

   OBC Reference(s): ____________________

2. An unreinforced concrete footing in a Part 3 *building* is to be designed to support a factored column load of 1500 kN. Which of the following should be used to execute the footing design?
   - a) Division B, Subsection 9.15.3
   - b) The *subsurface investigation* report
   - c) CAN/CSA-A23.3
   - d) The factored geotechnical resistances stated in the *subsurface investigation* report, and the methods of CAN/CSA-A23.3

   OBC Reference(s): ____________________

3. The approved *building* permit drawings show that a reinforced concrete footing is to be constructed as 3000 mm x 2000 mm x 400 mm thick. During construction, it is determined that the footing has been constructed as 4000 mm x 2000 mm x 400 mm thick.
Which of the following must be done?

   a) The footing must be removed and replaced

   b) 1000 mm of concrete must be removed

   c) The *designer* must assess the as-built condition and make any necessary design changes

   d) No action is required. The larger *foundation unit* places less stress on the soil, and is therefore acceptable.

OBC Reference(s): __________________

4. For the *building* in question 2 above, it is discovered that several *footings* have been become cracked and chipped due to accidental impact by construction vehicles. Which of the following must be done?

   a) The *footings* must be removed and replaced

   b) The cracks and chips must be repaired.

   c) The piles must be repaired as directed by the *Chief Building Official*.

   d) The *designer* must assess the as-built condition

   OBC Reference(s): __________________

STOP

9.6.2 Deep Foundations

A *deep foundation* is a *foundation unit* that provides support for a *building* by transferring load to *soil or rock*, at a considerable depth below the *building*. *Deep foundations* are normally used where *shallow foundations* are not possible, often due to poor *soils* at or near the surface, or if the shallow bearing stratum is underlain by weak or compressible *soil*. *Deep foundations* are also used where unusually large loads are expected, or where the design of the *building* has restrictive limits on anticipated settlement.

Deep foundations may be installed by driving, jacking, jetting, auguring or screwing, drilling or with *excavation*. *Deep foundations* are classified by the degree to which they displace the *soil* upon installation. Types of *deep foundations* include:

Large displacement *piles* (also called "driven *piles*"):

- Timber *piles*
- Precast concrete *piles*
- Closed-end steel pipe *piles* (may be concrete-filled)
- Closed-end tubular concrete *piles*

Small displacement *piles*:

- Steel H-*piles*
- Open-end steel pipe *piles*
- Anchor or screw *piles*
- Preformed *piles* in pre-bored or jetted holes

Non-displacement *piles* (in which a void is formed in the *soil* by boring, and may require the use of liners):

- Concrete shafts and piers
- Auger cast grout *piles*

Exercise #9-6

With reference to Subsection 4.2.7, complete the following exercise. Then discuss your answers with your group.

1. Which of the following are means by which *deep foundations* transfer structural loads to *soil* or *rock*?

   a) End bearing

   b) Skin friction or adhesion

   c) Both a) and b), either singly or in combination

   d) Neither a) nor b)

OBC Reference(s): ____________________

2. Who may oversee *pile* load tests?

   a) *Chief Building Official*

   b) *Professional Engineer*

   c) Person especially qualified

   d) General Contractor

   OBC Reference(s): ____________________

3. In the structural design of a steel *pile* for axial compression, what portion of the *pile* is considered to be laterally unsupported?

   a) The portion of the *pile* embedded in the *pile* cap

   b) The portion of the *pile* in contact with the soil

   c) The portion of the *pile* not in contact with soil or embedded in concrete

   d) None of the above

OBC Reference(s): ____________________

4. Other than structural loads and materials, list the considerations that must be taken into account in the design of *deep foundations*.

	Situation	Code Reference
a)		Sentence 4.2.4.2.(1)
b)		Clause 4.2.7.2.(3)(a)
c)		Clause 4.2.7.2.(3)(b)
d)		Clause 4.2.7.2.(3)(c)
e)		Sentences 4.2.7.2.(4) and (5)
f)		Sentence 4.2.7.2.(6)

5. The drawings for a *building* specify that the tolerance for location of precast concrete *piles* is 75 mm in any direction. During construction, it is determined that several *piles* have been placed 250 mm from their specified locations. Which of the following must be done?

   a) The piles must be removed and replaced

   b) Additional *piles* must be provided and the design of the *pile* caps modified

   c) The *designer* must assess the as-built condition

   d) No action is required.

   OBC Reference(s): ____________________

6. For the *building* in question 5 above, it is discovered that several *piles* have been become cracked and distorted due to accidental impact by construction vehicles. Which of the following must be done?
   - a) The *piles* must be removed and replaced
   - b) Additional *piles* must be provided and the design of the *pile* caps modified
   - c) The piles must be repaired as directed by the *Chief Building Official*.
   - d) The *designer* must assess the as-built condition and make any necessary design changes

   OBC Reference(s): ____________________

9.6.3 Special Foundations

Exercise #9-7

Read Subsection 4.2.8 of the Building Code.
Complete the following exercise, then discuss your answers with your group.

1. Following a fire that destroys a *building*, it is proposed to construct a new *building* on the existing *foundations*. The new *building* is not an exact duplicate of the original *building*. Is a *subsurface investigation* required?

   ☐ Yes ☐ No

   Why? ____________________________

   ____

   OBC Reference(s): ____________________

2. For the proposed construction in question 1, is a structural investigation and analysis of the existing concrete *foundations* required?

☐ Yes ☐ No

Why? ________________________________

____

OBC Reference(s): ________________________

STOP

9.7 FIELD REVIEW OF CONSTRUCTION

While *subsurface investigations* provide information essential to the design of *foundations*, much of the information is collected on a sampling basis. It is not uncommon for *soil* and *rock* conditions to vary across a *building* site, and for anomalies to occur between the locations of boreholes or test pits.

Since the design of *foundations* is therefore based on incomplete information, it is mandatory that field review of construction be carried out to confirm that the findings and recommendations of the *subsurface investigation* remain valid, and to determine whether construction may proceed without modifications to the design.

Articles 4.2.2.2 and 4.2.2.3 specify the requirements for field review of subsurface conditions during construction. It is common for the person preparing the *subsurface investigation* report to recommend and/or require that the extent of field review exceed the minimum requirements of the Code.

Exercise #9-8

Read Articles 4.2.2.2 and 4.2.2.3 and complete the following exercise. Then discuss your answers with your group.

1. Notwithstanding the requirements of Division C, who of the following may carry out field review, for the purpose of ensuring that subsurface conditions are consistent with those in the *subsurface investigation* report?

   a) General contractor

   b) Excavation subcontractor

   c) *Designer* or a suitably qualified person

   d) *Chief Building Official*

   OBC Reference(s): ______________

2. According to the Code, for which of the following is continuous field review of construction not required?

   a) *Deep Foundations*

   b) Engineered *fills* supporting *foundations*

   c) *Shallow foundations*

   d) Backfilling of retaining walls

   OBC Reference(s): ______________

3. According to the Code, what site conditions would require assessment and possible redesign of *foundations*?

   a) ________________________________

   OBC Reference: ________________

   b) ________________________________

   OBC Reference: ________________

   c) ________________________________

   OBC Reference: ________________

4. If subsurface conditions are found to be different from those assumed in the design, who must assess the adequacy of the *foundation* design?

   a) *Designer*

   b) *Professional Engineer*

   c) Person especially qualified in this field

   d) Geotechnical engineer

   OBC Reference(s): ______________

5. Is field review of *excavations* required?

   ☐ Yes ☐ No

   Why? ______________________________

   ____

   OBC Reference(s): ____________________

STOP End of Module 9

MODULE 10

GENERAL STRUCTURAL REQUIREMENTS
PART 9 BUILDINGS

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10.0 INTRODUCTION

In this Module, we will learn the general requirements for structural design using Part 9 of the Building Code, review general requirements for typical *building* materials, and determination of structural loading.

10.1 OBJECTIVES

Upon completion of this Module participants will be able to:

- Identify the limitations of design under Part 9 and be able to identify situations when Part 4 must be used;
- Identify material requirements for Part 9;
- Use the climatic data tables in the Supplementary Standard SB-1 to determine snow loads for Part 9 *buildings;*
- Recognize the importance of spans in determining snow loads for Part 9 *buildings;*

10.2 BASIS OF STRUCTURAL DESIGN IN PART 9 BUILDINGS

Subsection 1.1.2 of Division A defines the applicability of each Part of the Building Code. Article 1.1.2.4 of Division A defines how Part 9 of Division B is to be applied to *buildings*.

Generally, for Part 9 to apply, the *building* must be:

- Between ten and not exceeding 600 square metres in *building area;*
- Three storeys or less in *building height;*
- Used for an *occupancy* of:

a) Group C, *residential occupancies*
b) Group D, *business and personal services occupancies*,
c) Group E, *mercantile occupancies*,
d) Group F, Division 2 and 3, *medium* and *low hazard industrial occupancies*.

Other exceptions to the use of Part 9 can be found within Part 9 itself. As the scope of this Module is only the general structural provisions, we will review these general exceptions here only.

Some areas where Part 9 redirects the user to Part 4, are:

- Reinforced concrete design (Sentence 9.3.1.1.(3))
- Machine stress rated lumber (Article 9.3.2.3)
- Structural members and connections not specifically prescribed in Part 9, or outside the limitations of Part 9 (Article 9.4.1.1)
- Design snow loads for special roof trusses with spans greater than 6 metres (Sentence 9.4.2.2.(3))
- Special condition *foundations* (Subsection 9.4.4)
- Roof trusses not conforming to the loading and deflection requirements of Sentence 9.23.13.11.(1)
- Design snow loads for wood trusses or other structural members with spans larger than 12.2 m or spacing greater than 600 mm (Sentence 9.4.2.1.(1))

The need to design specific components to Part 4 of the Building Code does not imply that the remaining portions of the *building* have to be designed to Part 4 as well. However, portions of a *building* required to support the loads of Part 4 must also be designed to comply with Part 4. (Article 9.4.1.1)

These exceptions and others to Part 9 applicability will be covered in greater detail within individual Modules of this course.

Exercise #10-1

Read Articles 1.1.2.2 to 1.1.2.4 of Division A, including any referenced Articles or Sentences. Complete the following exercise, then discuss the answers with your group.

1. Define the following terms as referenced in the Building Code.

Building Height:

____

____

____

Building Area:

____

____

____

Residential Occupancy:

____

____

____

____

Mercantile Occupancy:

____

____

____

OBC Reference(s): ____________________

2. A new single storey, 300 square meter equipment storage *building* for a dairy farm located near Barrie, Ontario is to be designed and constructed in conformance with Supplementary Standard SB-11.
   Which Article or Sentence of Division A would require this *building* to comply with the structural provisions of the National Farm Building Code?

   a) 1.1.2.4(1)

   b) 1.1.2.2.(1)(b)

   c) 1.3.1.2

   d) 1.3.1.2.(4)

3. Which of the following *building* projects could be designed by Part 9 of the OBC:

   a) A 50 square metre renovation within a single storey existing 300 square metre Part 9 home that was built 8 years ago.

   b) A new, single storey strip mall having a building area of 800 square metres with individual units not exceeding 200 square metres.

   c) A new four-storey residential building having a building area of 500 square metres.

   d) None of the above.

OBC Reference(s): ____________________

STOP

10.3 STRUCTURAL LOADS

All *buildings*, and parts thereof, must be designed and constructed to safely support the loads, forces and effects that are reasonably expected to occur on them during their expected lives.

Subsection 9.4.2 sets out conditions which must be met for the part 9 loads to be used in the design of certain building elements.

The method of snow load determination for Part 9 buildings is much simpler than for Part 4 buildings.

The values given in Columns 12 and 13 of Supplementary Standard SB-1 represent the 1-in-50 year Ground Snow Load (S_s) and the 1-in-50 year Associated Rain Load (S_r) respectively. These values are used in the formula:

$$S=C_b\,S_s + S_r$$

Where C_b is a basic snow load roof factor. For Part 9 *buildings* the factor is 0.45 for roofs where the width does not exceed 4.3 metres and is 0.55 for all other roofs. In no case shall the specified snow load (S) be less than 1.0 kPa.

There are instances in Part 9 where design is required under the provisions of Part 4.
For example, structural members in Part 9 *buildings* with framing exceeding the limitations of Article 9.23.1.1 must be designed in accordance with Part 4. However, in these cases, the snow loads may be determined using the provisions of Part 9 rather than Part 4, provided that the framing geometry complies with the requirements of Sentence 9.4.2.1.(1).

Special attention is given to the design of wood roof trusses under Part 9. If in the rare occasion that the trusses are not designed under Part 4, then the requirements of Sentence 9.23.13.11(1) apply, in which case the trusses must be capable of supporting a total ceiling load of 0.35 kPa plus 2.67 times the specified live roof load for 24 hours and meet deflection requirements in Table 9.23.13.11 when loaded with the ceiling load plus 1.33 times the specified roof snow load for 1 hour.

Due to the occurrence of large unbalanced snow loads on bowstring, arch or semi-circular roofs trusses, Sentence 9.4.2.2.(3) requires the snow loads for such trusses to be determined in accordance with Part 4, even in Part 9 *buildings*.

Exercise #10-2

Read Articles 9.4.2 and 9.4.3.
Complete the following exercise, then discuss your answers with your group.

1. What is the maximum wood floor joist spacing for the specified loads in the Subsection to apply:
   a) 406 mm
   b) 762 mm
   c) 600 mm
   d) 610 mm

   OBC Reference(s): ____________________

2. Consider a two-storey residential house conforming to Part 9 of the OBC, with plan dimensions of 10.0m x 12.0 m and a conventional wood-framed roof. What would be the specified roof snow load if the house were built in the following locations in Ontario?
   a) London ____________________
   b) Parry Sound ____________________
   c) Sault Ste. Marie ____________________
   d) Toronto ____________________
   e) Wawa ____________________

3. What is the minimum specified snow load, under Part 9 of the Code, and the applicable Code reference?

4. According to Table 1.2 of the Supplementary Standard SB-1, Petawawa has a 1-in-50 year ground snow load of S_s = 2.6 kPa, and an associated 1-in-50 year rain load of S_r = 0.4 kPa.
   What design *live load* should be used for a 4.2 m wide residential balcony (not used as a passageway), if the *building* conforms to Part 9 and serves a single dwelling unit?

   a) 2.32 kPa

   b) 1.60 kPa

   c) 1.90 kPa

   d) 4.80 kPa

   OBC Reference(s): ______________________

5. Using Table 9.4.3.1 what is the maximum allowable deflection, expressed as ratio of the clear span, for a beam supporting a floor?

STOP

10.4 LUMBER GRADING AND TYPES

Lumber grading in Canada is done according to the 'Standard Grading Rules' published by the National Lumber grading Authority (NLGA) and approved by the Canadian Lumber Standards Administration Board (CLS).

Each piece of lumber that is graded is stamped by the grading agency with a CLS certified grade stamp. A facsimile of the grade stamp, for the Canadian Lumbermen's Association, is shown below.

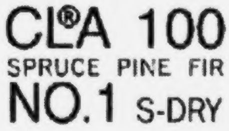
CL®A 100
SPRUCE PINE FIR
NO.1 S-DRY

Figure 10: 1
Sample Lumber Grade Stamp

There are five important pieces of information provided in the grade stamp as shown below.

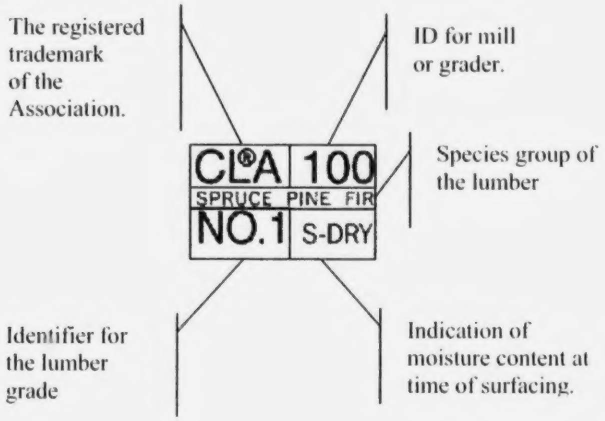
The registered trademark of the Association.
ID for mill or grader.
CL®A 100
SPRUCE PINE FIR
NO.1 S-DRY
Species group of the lumber
Identifier for the lumber grade
Indication of moisture content at time of surfacing.

Figure 10: 2
Grade Stamp Identification Marks

A list of facsimiles of grade marks used by Canadian lumber manufacturing associations and agencies authorized to grade mark lumber is included Appendix A – Volume 2 of the Code (Table A-9.3.2.1.B)

Table A-9.3.2.1.A 'Species Designations and Abbreviations' in the same appendix provides a list of permitted abbreviations for lumber species on grade stamps. The list is summarized here:

1. Douglas Fir – Larch (D Fir – L (N))
2. Hemlock – Fir (Hem – Fir (N))
3. Spruce – Pine – Fir (S-P-F) or (Spruce – Pine – Fir)
4. Northern Species – (North Species)

The Code requires that lumber used for joists, rafters, trusses and beams and for specific end uses defined in Table 9.3.2.1 be identified by a grade stamp.

Visually graded lumber has been a reliable way of assuring consistent quality for many years. Newer systems using machines to sort the lumber into grades are now in use. One of these lumber products, machine-stress rated [MSR] lumber, has been used for many years in highly demanding engineered applications. MSR is a specialty lumber product falling within the size parameters of dimension lumber and is required to conform to the requirements of Subsection 4.3.1.

Exercise #10-3

Read Subsection 9.3.2.
Complete the following exercise, then discuss the answers with your group.

1. Using Table 9.3.2.1 what is the minimum lumber grade that is permissible to use for non-*loadbearing* stud wall members.
    a) No. 3, Common
    b) Standard, No. 2
    c) Stud, Standard, No. 2
    d) Stud, Utility, No. 3

2. List three allowable uses in Part 9 construction for No. 3 Common Boards:

   a) ______________________________

   b) ______________________________

   c) ______________________________

   OBC Reference(s): ______________________

3. What are the three pieces of information required to be legibly identified on the face of OSB, waferboard and plywood used for roof sheathing, wall sheathing and subflooring

   a) ______________________________

   b) ______________________________

   c) ______________________________

   OBC Reference(s): ______________________

4. What is the maximum allowable moisture content of lumber at the time of installation?

   a) 0 %

   b) 15 %

   c) 19 %

   d) 28 %

   OBC Reference(s): ______________________

5. Which of the following situations are not acceptable in a locality where termites are known to occur?
   a) A structural wood element pressure treated to resist decay, has a clearance from the ground of 100 mm.
   b) A structural wood element has a clearance from the ground of 500 mm.
   c) A structural wood element is in contact with the ground, but the wood is pressure-treated with a chemical toxic to termites.
   d) Where the foundations are constructed such that inspection will be possible in the future, there is a plastic barrier to separate the foundation from the rest of the *building*.

OBC Reference(s): ______________________

STOP

10.5 CONCRETE AND MASONRY MATERIALS

Subsection 9.3.1 defines the conditions, materials, and performance requirements for nominally unreinforced concrete for *buildings* that meet the design requirements for Part 9.

Concrete is basically a mixture of three components, aggregates, cementitious materials and water. A chemical reaction, called hydration, between the cementitious materials and the water is the process that forms a hardened cement paste that binds the aggregates together to form the rock-like mass known as concrete.

One additional component or admixture for concrete referenced in Part 9 is Air Entrainment. Air entrainment introduces microscopic bubbles to provide free space within the paste to relieve pressure when trapped water within concrete freezes.

Reinforced concrete shall be designed in accordance with the provisions of Part 4 with a few exceptions. One exception is for flat insulating concrete form walls that are subject to specific requirements not in Sentence 9.3.1.1.(4). The other exception is with respect to reinforced concrete slabs that meet the requirements of Section 9.40.

Part 9 prescribes the minimum required compressive strength of concrete as:

- Minimum concrete strength required in Part 9 is 32 MPa for garage and carport floors and all exterior flatwork. (OBC 9.3.1.6)
- Slabs on ground must have a compressive strength of 25 MPa if dampproofing is not provided (OBC 9.16.4.5), and
- All other applications require a minimum of 15 MPa.

Article 9.15.2.2 provides the requirements for unit masonry construction used in the construction of foundation walls. Above ground masonry walls and interior masonry foundation walls not subject to lateral earth pressure shall conform to Section 9.20.

Article 9.15.2.4 provides that the requirements for wood frame foundations are required to conform to CAN/CSA-S406 "Construction of Preserved Wood Foundations" or to Part 4 of the Code.

Exercise #10-4

Read Article 9.3.1. Complete the following exercise, then discuss the answers with your group.

1. Which is the applicable reference standard that states the provisions under which concrete be designed, mixed, placed, cured, and tested?

____

OBC Reference(s): __________________

2. Name four different types of aggregates that could be used in a concrete mix provided that they conform to CAN/CSA-A23.1 "Concrete Materials and Methods of Concrete Construction"?

a) ___________________________

b) ___________________________

c) ___________________________

d) ___________________________

OBC Reference(s): _________________

3. What is the acceptable range of percentage air entrainment for concrete in garage floors, exterior steps and carport floors?

____

OBC Reference(s): ____________________

4. The weather forecast for tomorrow morning is for an air temperature of 3°C and the high temperature is not expected to go over 10°C for the next three days. What special preparations will be required if you are to be placing new concrete foundations tomorrow? (See also Article 9.12.1.3)

    a) ____________________________________
    b) ____________________________________
    c) ____________________________________
    d) ____________________________________

    OBC Reference(s): _________________________

5. For site mixed concrete conforming to the concrete mixes in Table 9.3.1.7, what is the acceptable water : cement ratio for concrete to be placed in a *foundation wall*?

____

OBC Reference(s): _________________________

STOP

10.6 METAL MATERIALS

Subsection 9.3.3 defines the requirements for sheet metal and galvanized sheet metal for *buildings* that meet the design requirements for Part 9.

Article 9.3.3.1 defines that the minimum thickness for sheet material given in Part 9 refers to the actual minimum base metal thickness measured at any point of the material. It further clarifies that for galvanized steel, the thickness is to include the coating unless specifically indicated otherwise.

Article 9.3.3.2 brings our attention to two specifications that zinc coatings must conform to that are used on sheet steel intended for use in locations exposed to weather or as a flashing material.

The specifications referenced are the G90 coating designation of either:

- ASTM A653/A653M "Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvanealed) by the Hot-Dip Process" , or
- ASTM A792/A792M, "Sheet Steel, 55% Aluminum – Zinc Alloy – Coated by the Hot-Dip Process"

Structural steel beams used to support floors and roofs for Part 9 *buildings* shall meet the requirements for Grade 350W steel in CAN/CSA-G40.21, "Structural Quality Steel" as required by Sentence 9.23.4.3.(2).

STOP End of Module 10

MODULE 11

FOOTINGS – PART 9 BUILDINGS

BUILDING STRUCTURAL – 2006

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11.0 INTRODUCTION

In this Module, we will learn the requirements for footings and *excavations* as they relate to the construction of *buildings* that conform to Part 9.

11.1 OBJECTIVES

Upon completion of this Module participants will be able to:

- Identify situations in Part 9 *buildings*, where design under Part 4 is required,
- Determine how to determine a bearing pressure for a given *soil* type,
- Recognize the requirements for *excavations*,
- Determine minimum depth of footings,
- Determine size and thickness of un-reinforced footings prescribed by the Building Code,
- Identify situations in which footings must be stepped,
- Recognize the limitations of conventional footings and provisions for alternate *foundation* types,
- Describe the limitations of slabs on grade to support structural and hydrostatic loads.

11.2 APPLICABILITY OF PART 9 FOUNDATION PROVISIONS

There are many restrictions to the design of footings under the provisions of Part 9 as defined in Section 9.15 – Footings and Foundations. The intent for this Section of the Code is to provide a simplified method for design of footings for Part 9 *buildings* on "problem-free" *soils* and without a surcharge.

Soil or *building* conditions that do not meet these requirements, or have other special considerations will require that the *foundations* to be designed under Part 4 of the Code.

Exercise #11-1

Review Subsection 9.15.1.
Answer the following questions, then discuss the answers with the group.

1. Which of the following are acceptable conditions for application of Section 9.15?

   a) A wood framed *foundation* wall not subject to a surcharge on a stable soil with an *allowable bearing pressure* of 50 kPa.

   b) A three-storey high light frame *building* with flat insulating form *foundation* walls, not subject to a surcharge, on a stable *soil*. The soil has an *allowable bearing capacity* of 150 kPa. The *building* only contains a single *dwelling unit*.

   c) A concrete *foundation* wall and footing on a stable *soil* with an *allowable bearing capacity* of 100 kPa. The *building* is of masonry construction.

   d) In an area subject to permafrost a concrete *foundation* wall not subject to a surcharge with an *allowable bearing capacity* of 75 kPa and the *building* is of wood frame construction.

   e) None of the above.

   f) a) and d) only

OBC Reference(s): ________________

STOP

11.3 ALLOWABLE BEARING CAPACITY OF SOIL

While Subsection 9.4.4 of the Code provides generic maximum *allowable bearing pressures* for typical *soils* and typical Part 9 structures, it is important to remember that actual allowable strength of a *soil* stratum is determined through investigation combined with experience and mathematical models. If you are in doubt about the bearing capacity of a *soil*, be sure and consult a geotechnical engineer.

Soil bearing capacity is not the only *soil* property that can affect the determination of the design of a *foundation* of a building. *Foundations* founded on undisturbed *soil* with weaker *soil* present below this *foundation* level can reduce the bearing capacity for the *foundation*. The Code provisions for high water table are covered in Articles 9.4.4.3 and Sentence 9.15.3.4.(3). Although these Code requirements are worded differently, the effect on footing design is the same. Refer to Figures 11:1 and 11:5.

The second *soil* condition this Subsection addresses is a condition where changes in *soil* moisture content can cause movement of the *foundation* resulting in damage to the *building*. An example of this would be expansive or sensitive clays. *Foundations* on *soils* with these properties shall be designed using Part 4 of the Building Code.

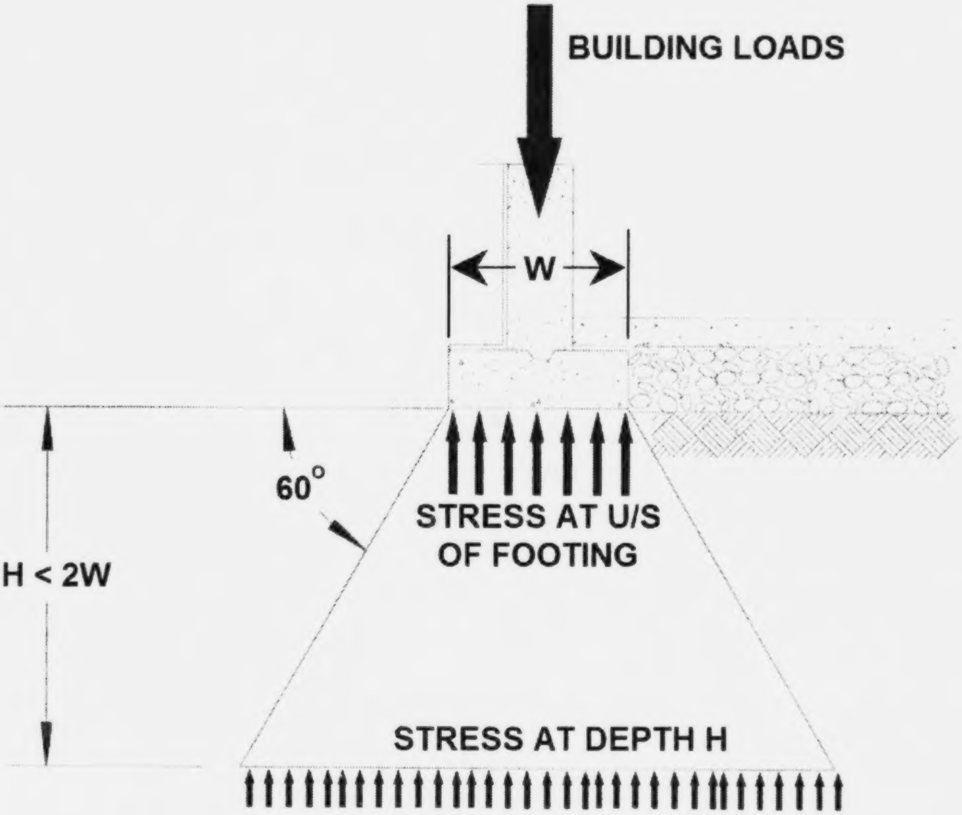

Figure 11:1
Bearing Stress at Depth (Article 9.4.4.2)

Exercise #11-2

Read Subsection 9.4.4 and answer the following questions. Then, discuss the answers with the group.

1. A 450 mm wide footing is to be placed on a *soil* that has a bearing capacity of 150 kPa. The *soil* is underlain by another *soil* stratum located 1000 mm below the level of the underside of the footing. The lower *soil* has a bearing capacity of 75 kPa. What value of *allowable bearing pressure* should be used for the design of the footings?

____

OBC Reference(s): ______________________

2. Complete the following table, taken from Table 9.4.4.1:

Type and Condition of *Soil*	Maximum *Allowable Bearing Pressure* (kPa)	Footing permitted to be designed under Part 9? (Yes/No)
Loose sand		
Compact silt		
Soft clay		
Firm clay		
Loose gravel		
Sensitive Clay		

OBC Reference(s): ______________________

____

____

3. Assume that a water table lies below the bearing surface of a footing by a distance less than the width of the footing. What effect does this water table have on the maximum allowable bearing pressure of gravel, sand or silt?

a) No effect

b) Increases the bearing capacity

c) Reduces the bearing capacity

d) Produces frost heave

OBC Reference(s): ______________________

STOP

11.4 QUESTIONABLE SOILS

Questionable soils are likely where:

- Excavated material reveals debris and garbage
- There is evidence of soil discolouration
- An *excavation* has surface water that does not originate from rainfall
- Pushing a rod or a 38 mm x 38 mm stake with a 45 degree end bevel into the soil demonstrates natural softness or softness created by previous disturbance

Wherever questionable *soil* of any type is involved, Articles 4.2.4.2 and 9.15.3.2 may be interpreted to mean that a subsurface investigation must be carried out.

It should be noted that Article 9.15.3.2 requires that *foundations* must be constructed on undisturbed *soil, rock or compacted granular fill* if designed and constructed under Part 9.

STOP

11.5 FOOTING DEPTH

Footings may not be placed directly at *grade*. Even in *buildings* without *basements*, footings are placed below grade in order to ensure they bear on sound undisturbed *soil* with sufficient bearing capacity and also protect them from damage due to frost.

The requirement to protect the footings from frost is due to the nature of water expanding when it freezes. Water trapped in the *soil* below the footings that is allowed to freeze expands and can lift the *foundation* causing damage to the *building*. The minimum depth required to adequately protect a footing from frost has been tabulated in Table 9.12.2.2 of the Code for different types of *soil*.

In addition, Sentence 1.2.1.1.(5) of Division C places limitations on the depth of footings constructed within the angle of repose of an adjacent *building*, where a professional engineer is not involved. An illustration of the effect of the allowable angle of repose is given in Figure 11:2.

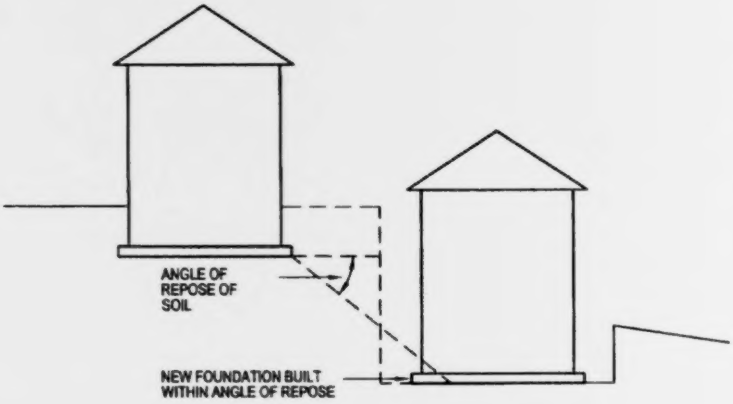

Figure 11:2
Angle of Repose

Exercise #11-3

Read Subsection 9.12.2 and Sentence 1.2.1.1.(5) of Division C. Answer the following questions, then discuss the answers with the group.

1. Which of the following has to meet a minimum depth of *foundation* below finished ground level?
   a) A *building* with a heated basement founded on *rock*.
   b) A *building* of masonry construction founded on clay that conforms to the requirements of the deformation resistance test in CAN/CSA-Z240.2.1, "Structural Requirements for Mobile Homes".
   c) A 45 square metre, single storey exterior deck (which does not support a roof), constructed 300 mm above *grade*, founded on clay.
   d) All of the above.

OBC Reference(s): ______________________

2. In a new Part 9 *building*, it is proposed to construct footings with a depth of 3.2 m below grade. The angle of repose of the soil is known to have an allowable rise-to-run ratio of 1:2, and the depth below grade of footings on an adjacent existing *building* is 2.4 m.
   If a *professional engineer* does not design the new *foundations*, what is the minimum horizontal separation between the footings?

____

OBC Reference(s): ______________________

STOP

11.6 MINIMUM FOOTING SIZES

Article 9.15.3.1 states that footings shall be provided under walls, pilasters, columns, piers, fireplaces and *chimneys* that bear on *soil* or *rock*. An exception to this is that footings may be omitted under piers or monolithic concrete walls provided that the required bearing pressure does not exceed the maximum *allowable bearing pressure* of the *soil* or *rock*.

Article 9.15.3.3 state the conditions where footing design using Subsection 9.15.3 is permissible. The necessary conditions include all of the following:

- *Foundation* walls of masonry, concrete or flat insulating concrete form *foundation* walls
- Above-ground walls of masonry, flat insulating concrete form foundation walls or light wood-frame construction
- Floors and roofs of light wood frame construction, with the spans of floor joists not exceeding 4.9 m
- *Live load* on any floor supported by the footing not to exceed 2.4 kPa.

Where the live loads on a floor exceeds 2.4 kPa, Sentences 9.15.3.3.(3) requires footing design in accordance with Section 4.2.

Where the floor joist spans exceed 4.9 m, Sentence 9.15.3.4.(2) allows design of footings using Section 4.2, or alternately, using the special provisions of Sentence 9.15.3.4.(2)

Article 9.15.3.4 of the Code provides a table of minimum footing sizes and conditions of their applicability, and Articles 9.15.3.5 and 9.15.3.6 describes how to modify these minimums to address some variability in typical house construction.

Exercise #11-4

Read Articles 9.15.3.3 to 9.15.3.6. Answer the following questions, then discuss the answers with the group.

1. What is the minimum required footing width for the following:

a) An interior, full height load bearing masonry wall, supporting 2 floors where the floor joists span approximately 3.9 metres to exterior walls and the floors support a live load of 2.0 kPa.

   i. 200 mm
   ii. 350 mm
   iii. 450 mm
   iv. 550 mm

b) An interior, wood framed *loadbearing* wall supporting 3 floors has floor joists spanning 5.2 metres to exterior walls on either side of the interior wall. The floors support a live load 2.0 kPa.

   i. 200 mm
   ii. 450 mm
   iii. 500 mm
   iv. 550 mm

c) An exterior loadbearing flat insulated concrete form *foundation* wall that extends up to support the second floor. The floor joists span 4.5 metres from an interior support. The entire exterior wall is clad with brick veneer.

   i. 350 mm
   ii. 500 mm
   iii. 550 mm
   iv. None of the above

2. What is the minimum required area of an interior footing that supports a column supporting two floors, if the column is spaced 3000 mm from other columns?

____

OBC Reference(s): ______________

STOP

11.7 ADDITIONAL FOOTING DESIGN CONSIDERATIONS

Figure 11:3 illustrates the footing projection beyond the face of the supporting element. For unreinforced concrete it is required that the footing be as thick (Dimension 'D') as the projection beyond the face of the supporting element (dimension 'P') and also not be less than 100 mm. Refer to Sentence 9.15.3.7.(1) and Article 9.15.3.8.

Step footings are a method to locally adjust the depth below grade along a wall footing having two different founding elevations.

As previously stated, the location of the water table in the ground below the *foundations* is very important as it has the effect of lowering (halving) the *allowable bearing pressure* for the *soil*. Part 9 has provided in Sentence 9.15.3.4.(3) the prescription that if the water table is less than the width of the footing below the bottom of the footing then the width of the footing shall not be less than twice the width required by Sentence 9.15.3.4.(1) and 9.15.3.4.(2).

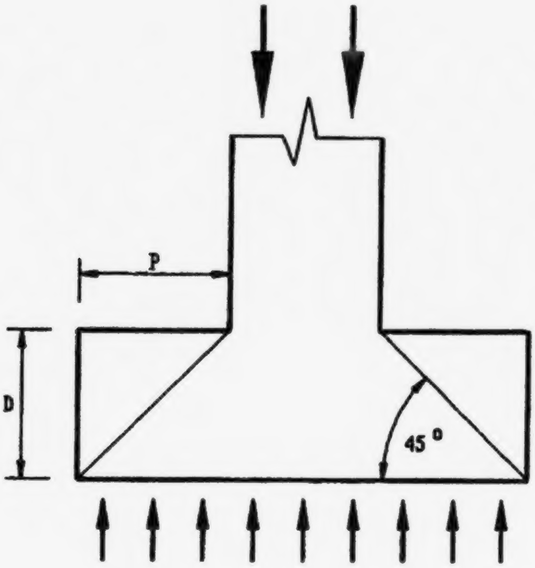

Figure 11:3
Footing Projection (Article 9.15.3.8)

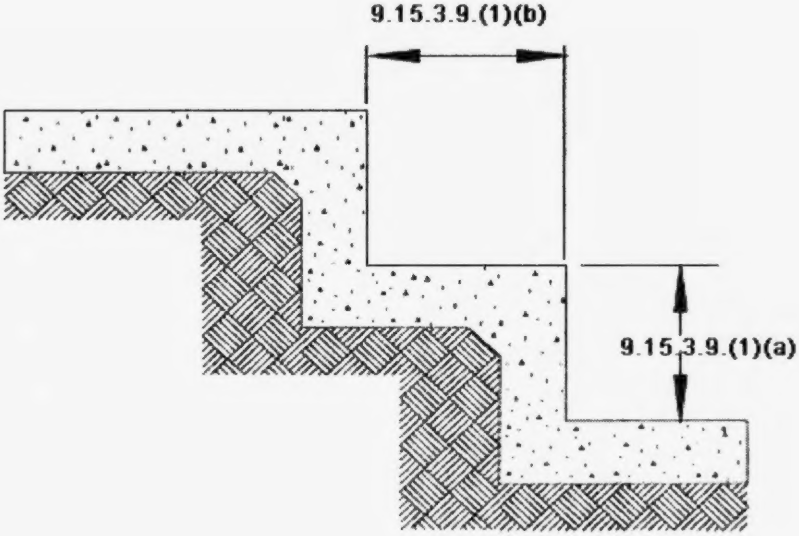

Figure 11:4
Step Footings

EXERCISE #11-5

Answer the following questions with reference to Articles 9.15.3.4 and 9.15.3.9, then discuss the answers with the group.

1. For the provided value of P (Horizontal projection beyond the face of the *foundation* wall), what is the minimum value of D (Thickness of footing) Refer to Figure 11:3:

   a) P = 50 mm D = _____

   b) P = 200 mm D = _____

   c) P = 100 mm D = _____

2. Considering an exterior wall footing. The water table is 500 mm below the footing. The *building* is a two-storey house with a wood frame and masonry veneer similar to Figure 11:2. The *soil* is sandy silt with 75 kPa *allowable bearing capacity*.
   What is the required wall strip footing width?

   a) 480 mm

   b) 960 mm

   c) 350 mm

   d) 700 mm

   OBC Reference(s): ________________

3. An unreinforced square footing for a steel column that meets the minimum requirements for spans and loading in a three-storey house. The columns and the 150 mm x 150 mm square steel base plates are supported on the footing. The columns are at 3.0 m spacing.
   What is the minimum required footing dimensions for a square footing supporting the base plate of the column?
   a) 400 mm x 400 mm x 100 mm
   b) 1000 mm x 1000 mm x 350 mm
   c) 1000 mm x 1000 mm x 425 mm
   d) 1000 mm x 1000 mm x 850 mm

   OBC Reference(s): ________________

STOP

11.8 EXCAVATIONS AND PRECAUTIONS

The preparation for footing construction is achieved by means of *excavation*. The purpose of an *excavation* is to expose a suitable *bearing surface* upon which the *foundations* may bear.

Articles 9.12.1.1 to 9.12.1.3 state the requirements for *excavations* and Article 9.12.1.4 states the precautions that must be made during *excavations*.

Once the *foundations* have been placed it is important not to simply backfill the *excavation* without considering the state of the *foundation* support. Subsection 9.12.3 states that *foundation* walls shall be braced or laterally supported prior to backfilling when required. Refer to Figure 11:5 for examples of bracing.

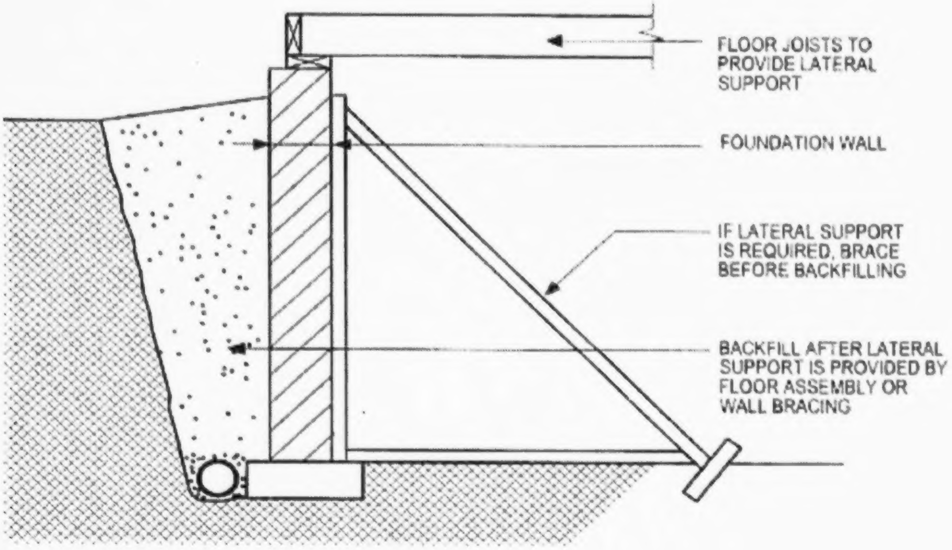
FLOOR JOISTS TO PROVIDE LATERAL SUPPORT
FOUNDATION WALL
IF LATERAL SUPPORT IS REQUIRED, BRACE BEFORE BACKFILLING
BACKFILL AFTER LATERAL SUPPORT IS PROVIDED BY FLOOR ASSEMBLY OR WALL BRACING

Figure 11:5
Backfill Bracing

Exercise #11-6

Read Subsection 9.12.1 and 9.12.3. Answer the following questions, then discuss the answers with your group.

1. Name three conditions that the bottom of an *excavation* shall be protected or free of?

a) ____________________________

b) ____________________________

c) ____________________________

OBC Reference(s): ____________________________

STOP

11.9 PIER FOUNDATIONS

Article 9.15.2.3 of the Code states the provisions for the use of these types of *foundations*. Where trenches are required beneath footings for sewers and water mains, the trench is to be filled in accordance with Article 9.12.4.1.

Exercise #11-7

Read Article 9.15.2.3 of the Building Code.
Answer the following questions, then discuss your answers with your group.

1. What is the maximum spacing, without special design of the piers or footings, for piers supporting the principal framing members of a single storey *building*?

   a) 4.3 m

   b) 4.9 m

   c) 3.5 m

   d) 6.0 m

   OBC Reference(s): ____________________

2. What is the maximum height of a 400 mm x 200 mm concrete block pier above grade?

   a) 1000 mm

   b) 600 mm

   c) 1200 mm to establish minimum frost cover.

   d) No maximum as pier is laterally restrained by *soil*.

   OBC Reference(s): ____________________

STOP

11.10 FLOORS ON GROUND

Article 9.16.1.2 requires that the design of slabs-on-ground that support loads from the superstructure are to be designed in conformance with Part 4. Wood framed floors on ground shall conform to CAN/CSA - S406, "Construction of Preserved Wood Foundations", as required by Article 9.16.5.1.

Additional forces requiring special attention are those due to hydrostatic pressure forces caused by ground water levels, as shown in Figure 11:6. Where hydrostatic forces are present on a floor on ground the floor shall be designed to resist the hydrostatic forces and shall be a cast-in-place reinforced concrete slab.

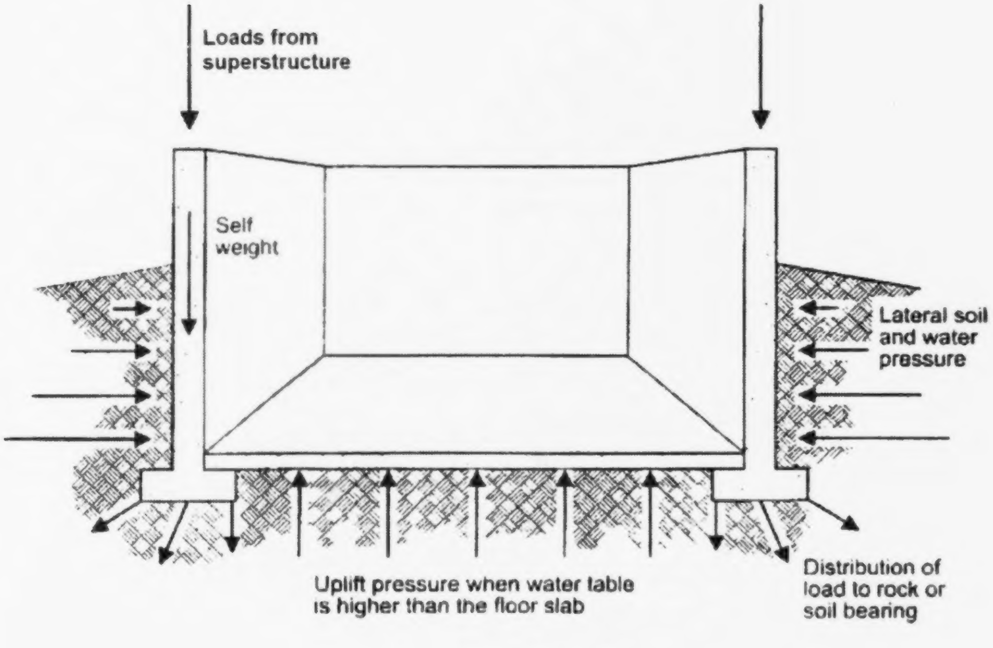
Loads from superstructure
Self weight
Lateral soil and water pressure
Uplift pressure when water table is higher than the floor slab
Distribution of load to rock or soil bearing

Figure 11:6
Foundation Loads

11.11 CARPORTS AND GARAGES

Subsection 9.35.3 provides some special provisions for the *foundations* for construction of Carports and Garages. However, in general the *foundations* for these types of structures are to conform with Sections 9.12 and 9.15 as discussed previously.

Exercise #11-8

Read Subsection 9.35.3. Answer the following question, then discuss the answer with the group.

1. What is the minimum pier size to support a carport column with dimensions of 100 mm x 100 mm?
   - a) 100 mm x 125 mm
   - b) 112.5 mm x 112.5 mm
   - c) 125 mm x 125 mm
   - d) 190 mm x 190 mm

   OBC Reference(s): ______________________

STOP End of Module 11

MODULE 12

FOUNDATION WALLS – PART 9 BUILDINGS

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12.7 Brick Anchorage 18
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12.0 INTRODUCTION

In this module, we will learn the requirements for *foundation* walls as they relate to the construction of *buildings* that conform to Part 9.

12.1 OBJECTIVES

Upon completion of this module participants will be able to:

- Identify situations in Part 9 *buildings* where design under Part 4 is required
- Recognize the concepts of lateral earth pressure, drainage and temporary bracing
- Identify the concept of lateral support of walls
- Identify the main issues in the design of *foundation* walls
- Determine maximum wall height and maximum height of backfill on a wall
- Select sizes of *foundation* walls using Part 9
- Identify the requirements to support joists, beams, structural framing, and above-grade masonry
- Recognize that brick veneer facing must be anchored to recessed *foundation* walls
- Address openings, recesses and corbels in *foundation* walls

12.2 LATERAL EARTH PRESSURE

In general, *foundation* walls span vertically between the top of the footings and first framed floor above grade, assuming no intermediate supports. Typically, these *foundation* walls create crawl spaces or *basements* below grade. Therefore, *foundation* walls are not only subject to the gravity loads induced from the floors and walls above grade, but also are required to hold back the soil from the interior space below grade. The force exerted on the wall due to the horizontal forces of soil is called 'lateral earth pressure'.

Another significant lateral force on *foundation walls* is 'hydrostatic pressure' due to free water in *soil*. The height of the water table and flood plain conditions influence this force.

Adjacent *foundations* and *buildings* that cause stress in soil can also result in lateral pressure on a *foundation* wall, if their *foundations* are at a higher level. This lateral loading and other 'surcharge' loadings are addressed in Sentence 9.4.4.6.(2).

STOP

12.3 LATERAL SUPPORT OF FOUNDATION WALLS

When the top of a *foundation* wall is restrained against movement, the capacity of a *foundation* wall to resist lateral earth pressure is greatly increased. The diagram in Figure 12:1 summarizes how the top of a *foundation* wall can be laterally supported. Refer to Article 9.15.4.3 for the applicable Code provisions.

Article 9.15.4.4 gives the Code provisions for required lateral support at the bottom, for flat insulated concrete form walls.

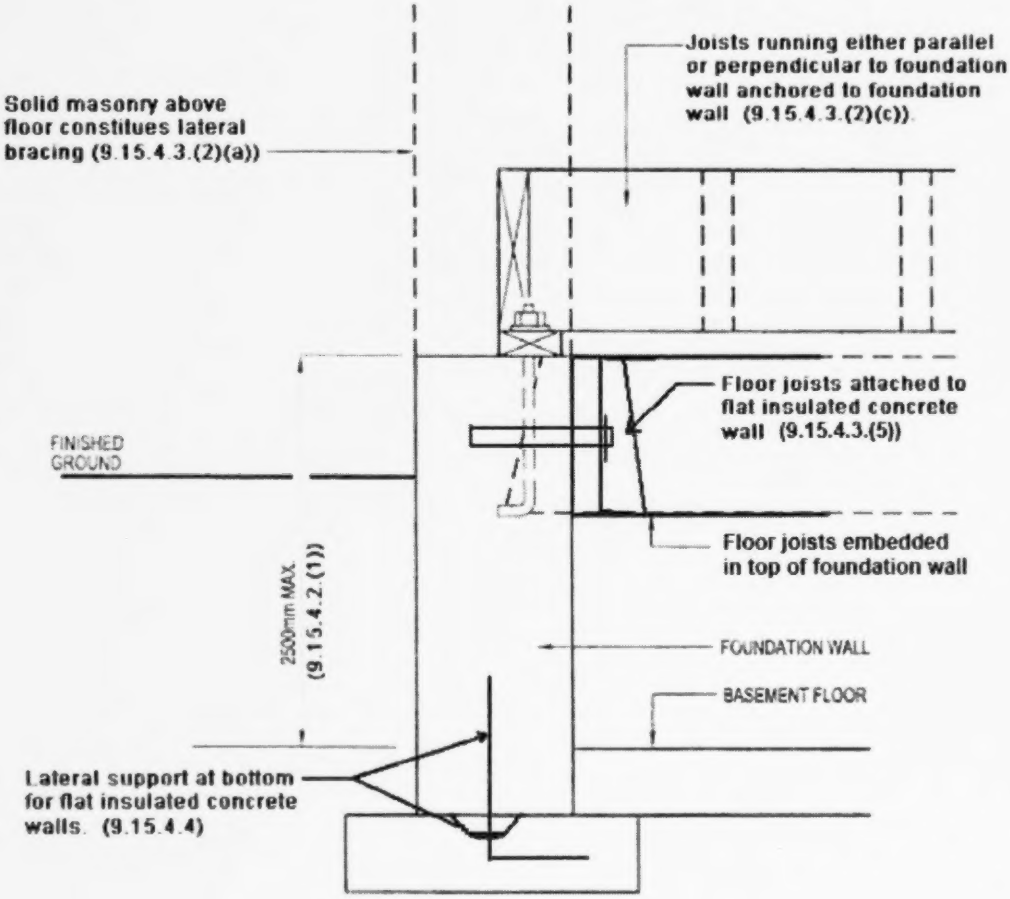

Joists running either parallel or perpendicular to foundation wall anchored to foundation wall (9.15.4.3.(2)(c)).
Solid masonry above floor constitues lateral bracing (9.15.4.3.(2)(a))
Floor joists attached to flat insulated concrete wall (9.15.4.3.(5))
FINISHED GROUND
Floor joists embedded in top of foundation wall
2500mm MAX. (9.15.4.2.(1))
FOUNDATION WALL
BASEMENT FLOOR
Lateral support at bottom for flat insulated concrete walls. (9.15.4.4)

Figure 12:1
Foundation Lateral Support

EXERCISE #12-1

Read Sentence 9.4.4.6.(2) and Articles 9.15.4.3 and 9.15.4.4. With reference to Figure 12:2, answer the following questions, then discuss your answers with your group.

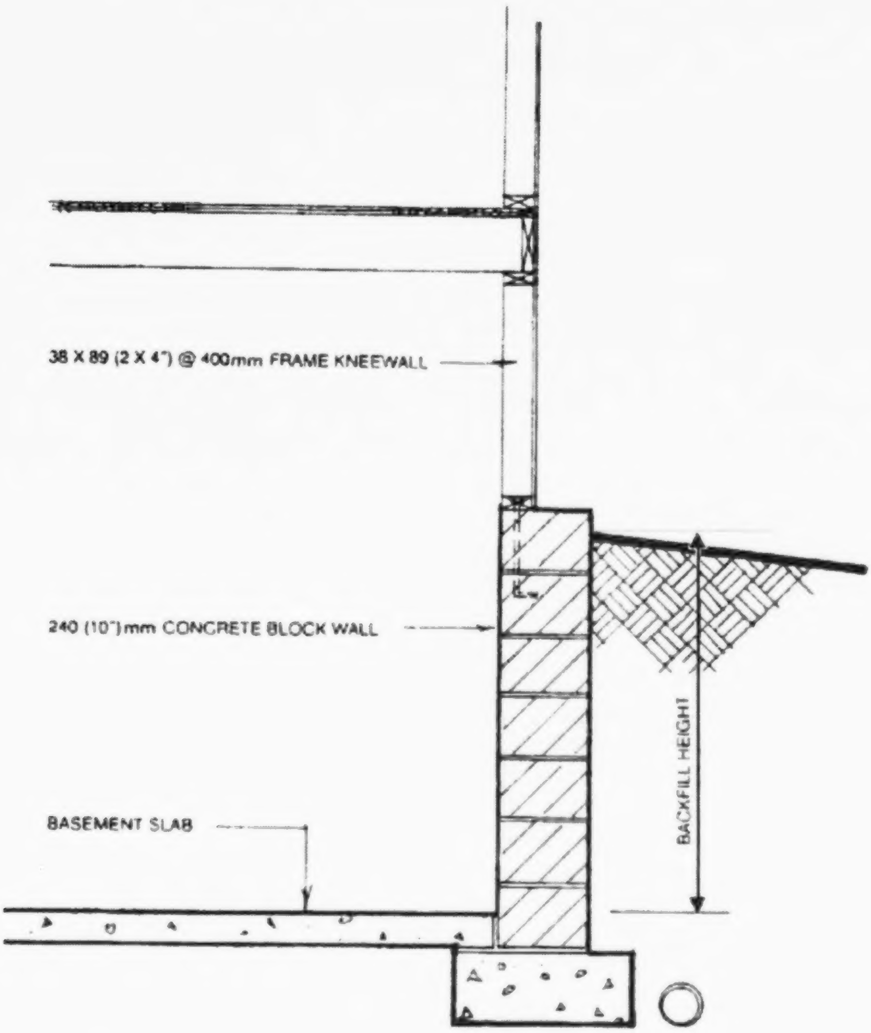

38 X 89 (2 X 4") @ 400mm FRAME KNEEWALL
240 (10")mm CONCRETE BLOCK WALL
BASEMENT SLAB
BACKFILL HEIGHT

Figure 12:2
Knee Wall Foundation Wall Section

1. In determining the maximum backfill height for the masonry *foundation* wall shown, would you consider the top of the masonry wall laterally supported?

   ☐ Yes ☐ No

   Why?

   ____

   ____

   ____

   ____

2. Which of the following provides required lateral support for a flat insulating concrete foundation wall. The wall contains no openings.

   a) Floor joists are installed according to Article 9.20.17.5.

   b) Foundation wall supports solid masonry.

   c) Floor joists are installed according to Article 9.20.17.5 and a concrete floor slab is installed in the basement.

   d) Floor joists are installed according to Article 9.20.17.5 and the bottom of the foundation wall is doweled into the footing with 20M reinforcing bars spaced at 900 mm on centre.

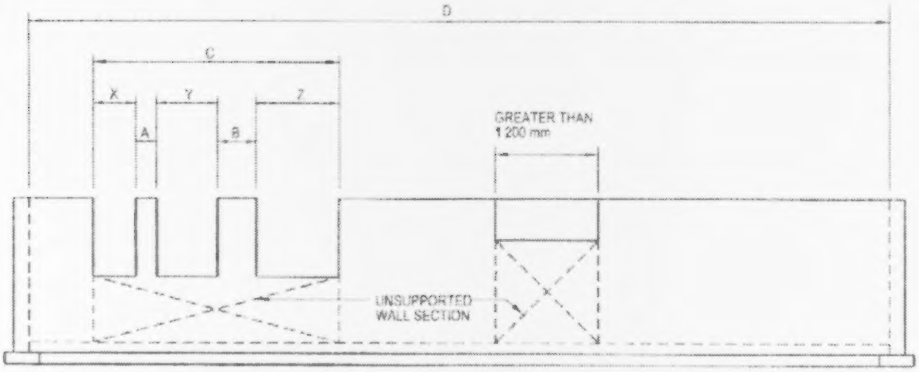
   OBC Reference(s): ______________

STOP

12.4 ALLOWABLE OPENINGS IN FOUNDATION WALLS

Openings made within *foundation* walls adversely affect the ability of the walls to resist lateral pressures. Sentences 9.15.4.3.(3) and 9.15.4.3.(4) provide direction on how one must decide whether an unreinforced foundation wall should be treated as laterally supported or laterally unsupported in the presence of openings. Figure 12:3 summarizes these conditions for unreinforced walls described in Sentence 9.15.4.2.(1).

Openings made in flat insulating concrete foundation walls are required to be reinforced according to Sentence 9.15.4.5.(4). Requirements for openings in reinforced masonry foundation walls are given in Sentence 9.15.4.2.8(b).



IF 'A' IS LESS THAN $\frac{X+Y}{2}$ THEN OPENING = X + A + Y

IF 'C' IS MORE THAN 25% OF 'D' OR 1 200 mm THEN WALL BELOW IS CONSIDERED UNSUPPORTED

Figure 12:3
Openings in Unreinforced Foundation Walls
(For unreinforced block or solid concrete walls described in Sentence 9.15.4.2.(1))

Exercise #12-2

Read Sentences 9.15.4.3.(3) and 9.15.4.3.(4) of the Code. With reference to Figure 12:3, answer the following questions, then discuss your answers with your group.

1. For a concrete block foundation wall, what special provisions would need to be in place to be able to consider the portion below an opening as laterally supported if the opening was greater than 1200 mm in width?

   ____

   ____

   OBC Reference(s): __________________

2. With reference to Figure 12:3:
   Consider a wall as described in Sentence 9.15.4.2.(1) that has three separate openings. Each opening is 300 mm X 300 mm and there is a 200 mm solid portion between each opening. There are no other openings in the wall and the wall is 4000 mm long.
   What is the size of the effective opening?
   (Horizontal x Vertical in mm)

   a) 800 mm x 300 mm

   b) 900 mm x 300 mm

   c) 1000 mm x 300 mm

   d) 1300 mm x 300 mm

   OBC Reference(s): ______________

STOP

12.5 WALL THICKNESS AND CONSTRUCTION

The design of *foundation* walls under Part 9 is subject to the conditions and limitations noted in Subsection 9.15.4. Sentence 9.15.4.2.(1) provides a table of minimum wall thicknesses for unreinforced construction and the presence of lateral support subject to the height of finished ground above the basement floor or crawl space.

Sentence 9.15.4.2.(4) provides requirements for reinforced concrete block foundation walls. Figure 12:4a provides a summary of required locations of reinforcement for reinforced concrete block masonry subject to the conditions of 9.15.4.2.(4).

Article 9.15.4.1 requires that the material used to construct the permanent form material to conform to the performance requirements of CAN/ULC-S701, "Thermal Insulation, Polystyrene, Boards and Pipe Covering". Article 9.15.4.5 provides the reinforcing requirements for flat insulating concrete form foundation walls. These reinforcing requirements are summarized in Figure 12:4b.

Articles 9.15.4.6 and 9.15.4.7 provide conditions regarding the top of the *foundation* wall with respect to minimum height above grade and reductions in wall thickness to accommodate floor joists or masonry veneer. Figure 12:5 provides a summary of these requirements.

Note the special Code requirements for masonry veneer supported on a *foundation* wall with a reduced thickness (also knows as a 'recess'). Where a wall recess is greater then that allowed by Code, then the wall would need to be considered as laterally unsupported.

Article 9.15.4.8, which permits the corbelling of masonry *foundation* walls for support of masonry veneer cavity walls, directs the user to 9.20.12.2 for the required limitations. Figure 12:6 provides a summary of these requirements.

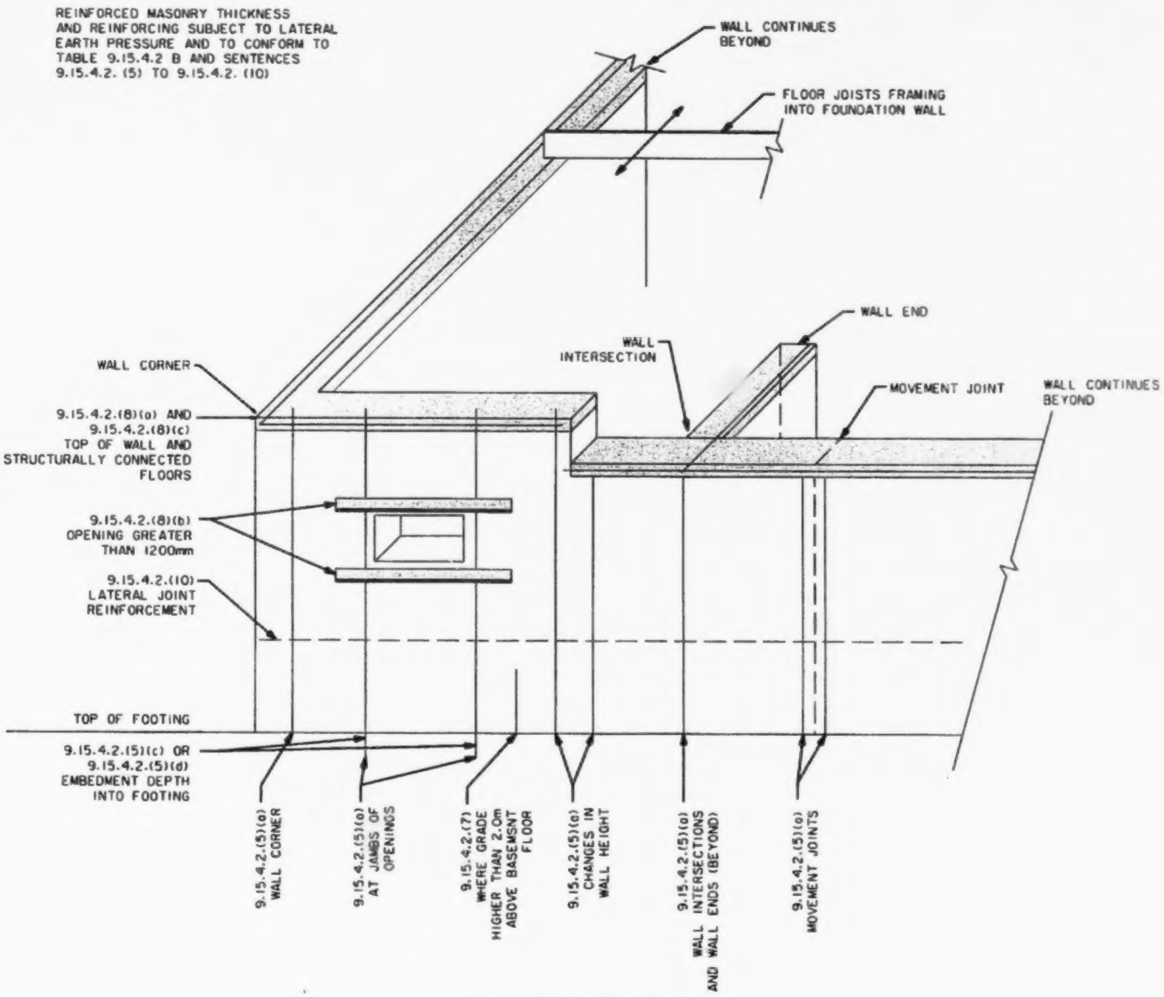
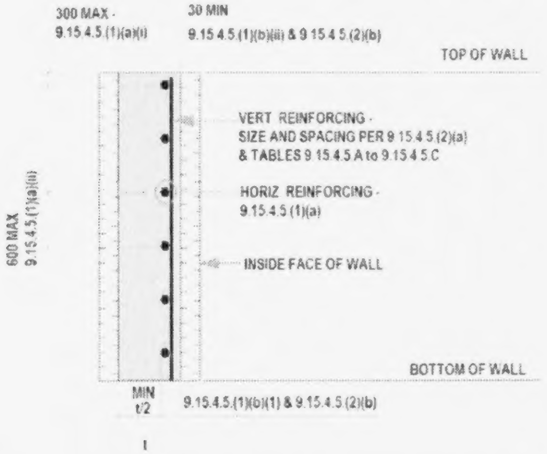
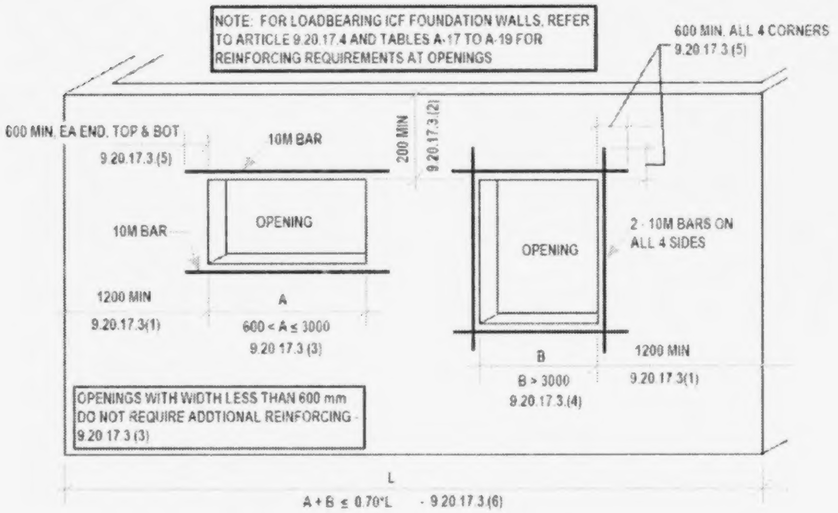

REINFORCED MASONRY THICKNESS AND REINFORCING SUBJECT TO LATERAL EARTH PRESSURE AND TO CONFORM TO TABLE 9.15.4.2 B AND SENTENCES 9.15.4.2.(5) TO 9.15.4.2.(10)
WALL CONTINUES BEYOND
FLOOR JOISTS FRAMING INTO FOUNDATION WALL
WALL END
WALL INTERSECTION
MOVEMENT JOINT
WALL CONTINUES BEYOND
WALL CORNER
9.15.4.2.(8)(a) AND 9.15.4.2.(8)(c) TOP OF WALL AND STRUCTURALLY CONNECTED FLOORS
9.15.4.2.(8)(b) OPENING GREATER THAN 1200mm
9.15.4.2.(10) LATERAL JOINT REINFORCEMENT
TOP OF FOOTING
9.15.4.2.(5)(c) OR 9.15.4.2.(5)(d) EMBEDMENT DEPTH INTO FOOTING
9.15.4.2.(5)(a) WALL CORNER
9.15.4.2.(5)(a) AT JAMBS OF OPENINGS
9.15.4.2.(7) WHERE GRADE HIGHER THAN 2.0m ABOVE BASEMSNT FLOOR
9.15.4.2.(5)(a) CHANGES IN WALL HEIGHT
9.15.4.2.(5)(a) WALL INTERSECTIONS AND WALL ENDS (BEYOND)
9.15.4.2.(5)(a) MOVEMENT JOINTS

Figure 12:4a

Reinforced Masonry Reinforcing Requirements – Sentence 9.15.4.2.(4)


300 MAX -
9.15.4.5.(1)(a)(i)
30 MIN
9.15.4.5.(1)(b)(ii) & 9.15.4.5.(2)(b)
TOP OF WALL
VERT. REINFORCING -
SIZE AND SPACING PER 9.15.4.5.(2)(a)
& TABLES 9.15.4.5.A to 9.15.4.5.C
HORIZ. REINFORCING -
9.15.4.5.(1)(a)
600 MAX
9.15.4.5.(1)(a)(ii)
INSIDE FACE OF WALL
BOTTOM OF WALL
MIN
t/2
9.15.4.5.(1)(b)(1) & 9.15.4.5.(2)(b)
t

ICF FOUNDATION WALL REINFORCING
CROSS-SECTION


NOTE: FOR LOADBEARING ICF FOUNDATION WALLS, REFER TO ARTICLE 9.20.17.4 AND TABLES A-17 TO A-19 FOR REINFORCING REQUIREMENTS AT OPENINGS

OPENINGS WITH WIDTH LESS THAN 600 mm DO NOT REQUIRE ADDTIONAL REINFORCING - 9.20.17.3.(3)

600 MIN. ALL 4 CORNERS
9.20.17.3.(5)
600 MIN. EA END, TOP & BOT
9.20.17.3.(5)
10M BAR
200 MIN
9.20.17.3.(2)
10M BAR
OPENING
OPENING
2 - 10M BARS ON
ALL 4 SIDES
1200 MIN
9.20.17.3(1)
A
600 < A ≤ 3000
9.20.17.3.(3)
B
B > 3000
9.20.17.3.(4)
1200 MIN
9.20.17.3(1)
L
A + B ≤ 0.70*L - 9.20.17.3.(6)

ADDITIONAL REINFORCING AT OPENINGS WIDER THAN 600 mm
IN NON-LOADBEARING ICF FOUNDATION WALLS
SENTENCE 9.15.4.5.(4)

Figure 12:4b
Reinforcing Requirements for Flat ICF Foundation Walls - Article 9.15.4.5

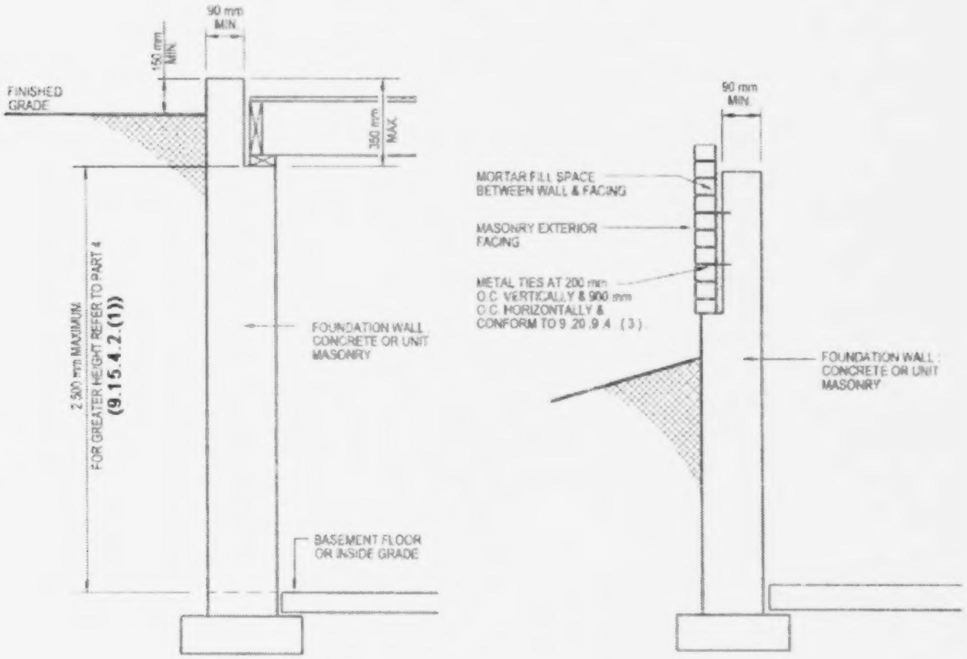

90 mm MIN
150 mm MIN
FINISHED GRADE
350 mm MAX
2 500 mm MAXIMUM
FOR GREATER HEIGHT REFER TO PART 4
(9.15.4.2.(1))
FOUNDATION WALL CONCRETE OR UNIT MASONRY
BASEMENT FLOOR OR INSIDE GRADE
90 mm MIN
MORTAR FILL SPACE BETWEEN WALL & FACING
MASONRY EXTERIOR FACING
METAL TIES AT 200 mm O.C. VERTICALLY & 900 mm O.C. HORIZONTALLY & CONFORM TO 9.20.9.4.(3)
FOUNDATION WALL : CONCRETE OR UNIT MASONRY

Figure 12:5
Reduced Wall Thickness – Article 9.15.4.7

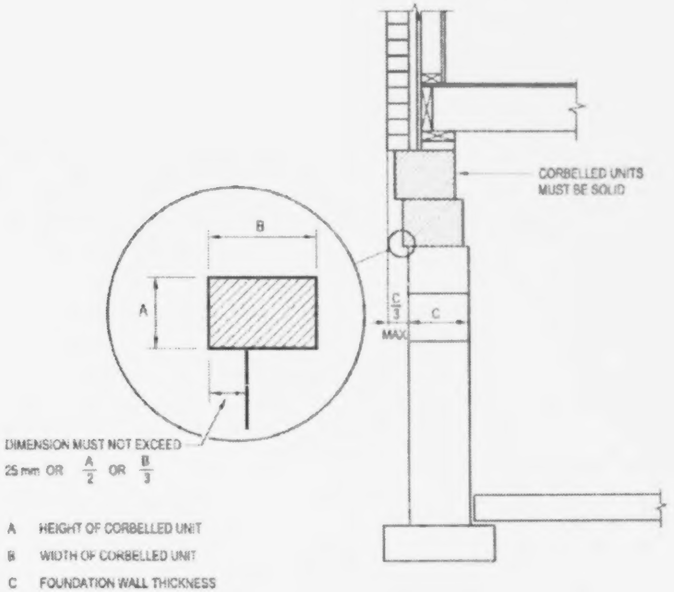
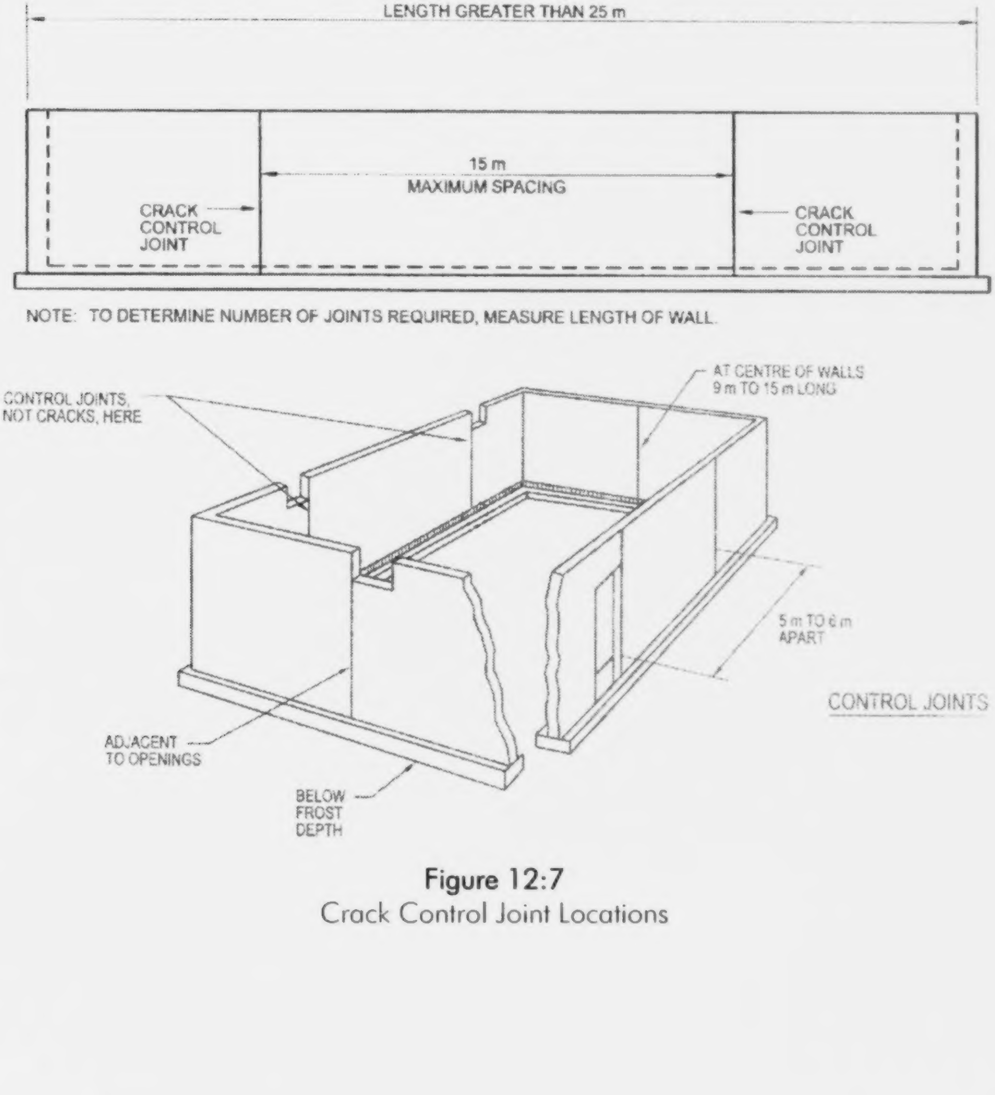

CORBELLED UNITS MUST BE SOLID
B
A
$\frac{C}{3}$ MAX
C
DIMENSION MUST NOT EXCEED
25 mm OR $\frac{A}{2}$ OR $\frac{B}{3}$
A HEIGHT OF CORBELLED UNIT
B WIDTH OF CORBELLED UNIT
C FOUNDATION WALL THICKNESS

Figure 12:6
Corbelling Limits – Article 9.15.4.8. Non-reinforced Foundation Walls

Foundation walls are often subject to moisture. The easiest way for moisture to enter through a *foundation* wall is through a crack. Understanding that concrete shrinks during the curing process, restraint against shrinkage can cause cracks to form to relieve the stress due to this shrinkage. However, by providing crack control joints in a *foundation* wall and sealing them properly we can maintain a moisture tight system.

Figures 12:7 to 12:9 provide a summary of the Code requirements given in Article 9.15.4.9 of the OBC.


LENGTH GREATER THAN 25 m
15 m
MAXIMUM SPACING
CRACK CONTROL JOINT
CRACK CONTROL JOINT
CONTROL JOINTS, NOT CRACKS, HERE
AT CENTRE OF WALLS 9 m TO 15 m LONG
5 m TO 6 m APART
CONTROL JOINTS
ADJACENT TO OPENINGS
BELOW FROST DEPTH

NOTE: TO DETERMINE NUMBER OF JOINTS REQUIRED, MEASURE LENGTH OF WALL.

Figure 12:7
Crack Control Joint Locations

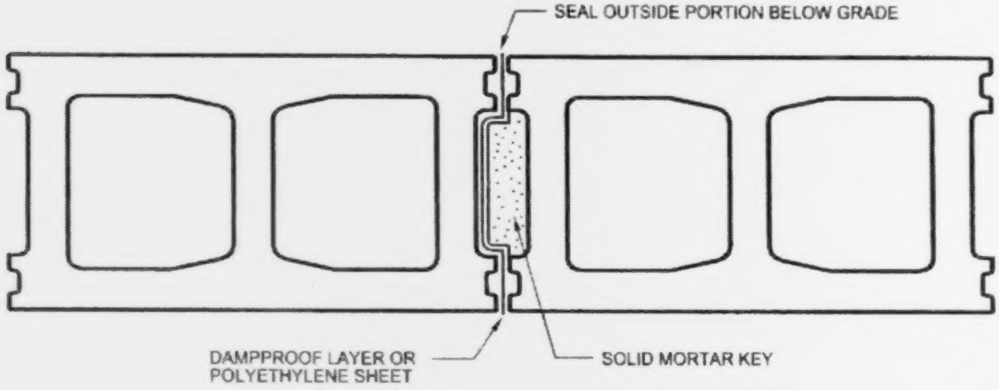

SEAL OUTSIDE PORTION BELOW GRADE
DAMPPROOF LAYER OR POLYETHYLENE SHEET
SOLID MORTAR KEY

Figure 12:8
Typical Masonry Mortar Key Detail – Sentence 9.15.4.9.(2)

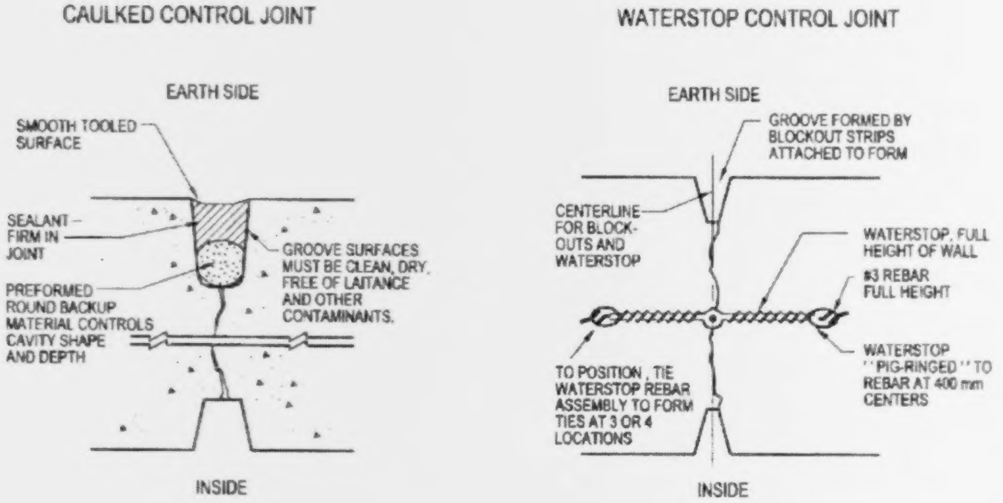

CAULKED CONTROL JOINT
EARTH SIDE
SMOOTH TOOLED SURFACE
SEALANT – FIRM IN JOINT
GROOVE SURFACES MUST BE CLEAN, DRY, FREE OF LAITANCE AND OTHER CONTAMINANTS.
PREFORMED ROUND BACKUP MATERIAL CONTROLS CAVITY SHAPE AND DEPTH
INSIDE
WATERSTOP CONTROL JOINT
EARTH SIDE
GROOVE FORMED BY BLOCKOUT STRIPS ATTACHED TO FORM
CENTERLINE FOR BLOCK-OUTS AND WATERSTOP
WATERSTOP, FULL HEIGHT OF WALL
#3 REBAR FULL HEIGHT
TO POSITION, TIE WATERSTOP REBAR ASSEMBLY TO FORM TIES AT 3 OR 4 LOCATIONS
WATERSTOP "PIG-RINGED" TO REBAR AT 400 mm CENTERS
INSIDE

Figure 12:9
Typical Control Joint Sealing Details – Sentence 9.15.4.9.(2)

Exercise #12-3

Read Articles 9.15.4.2 and Articles 9.15.4.5 to 9.15.4.9 of the Code. Answer the following questions, then discuss your answers with your group.

1. List the three main pieces of information required to determine the thickness of a *foundation* wall in accordance with Part 9.

   a) ______________________________

   b) ______________________________

   c) ______________________________

   OBC Reference(s): ________________

2. Consider the *foundation* wall shown in Figure 12:2. What is the maximum height of backfill allowed to be placed against the unreinforced masonry *foundation* wall?

   a) 2.30 m

   b) 1.40 m

   c) 1.80 m

   d) 1.20 m

   OBC Reference(s): ________________

3. What is the minimum required *foundation* wall thickness for a laterally supported 20 MPa concrete *foundation* wall that will be required to resist a maximum backfill height of 2.0 m of *soil*?

   a) 150 mm

   b) 200 mm

   c) 250 mm

   d) 300 mm

   OBC Reference(s): ________________

4. Which of the following conditions would not be acceptable for a laterally supported *foundation* wall that has a maximum height of 2.4 metres between the concrete basement floor and the exterior *grade*?

   a) A 190 mm thick laterally supported reinforced masonry wall with 25M vertical reinforcement spaced at 1000 mm on centre.

   b) A 240 mm thick laterally supported reinforced masonry wall with 25M vertical reinforcing at 1.8 metre spacing.

   c) A 240 mm thick laterally supported flat insulated concrete foundation wall with a 2.75 metre unsupported basement wall height. Wall is reinforced with 15M at 300 mm on centre.

   d) A 300 mm thick laterally supported solid 20 MPa concrete wall.

   OBC Reference(s): ______________

STOP

12.6 SUPPORT OF LOADS

Unit masonry *foundation* walls (concrete block walls) require special attention at the top to properly support the loads from floor joists and beams, and to ensure such walls are laterally supported.

Subsection 9.15.5 provides the requirements for tops of masonry foundation walls. Generally, the top course of the masonry wall must be filled with concrete to provide adequate bearing, and to allow embedment of anchor bolts for sill plates.

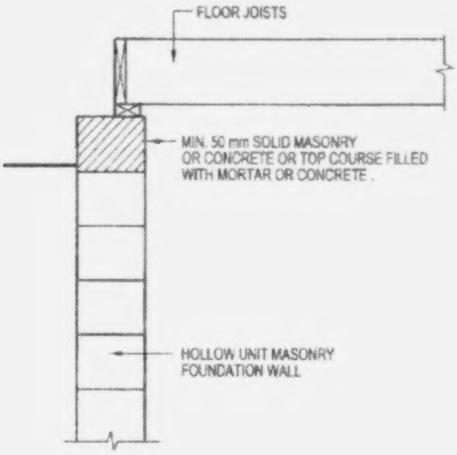

FLOOR JOISTS
MIN. 50 mm SOLID MASONRY OR CONCRETE OR TOP COURSE FILLED WITH MORTAR OR CONCRETE.
HOLLOW UNIT MASONRY FOUNDATION WALL

Figure 12:10
Floor Joist Bearing on Masonry Wall -- Article 9.15.5.1

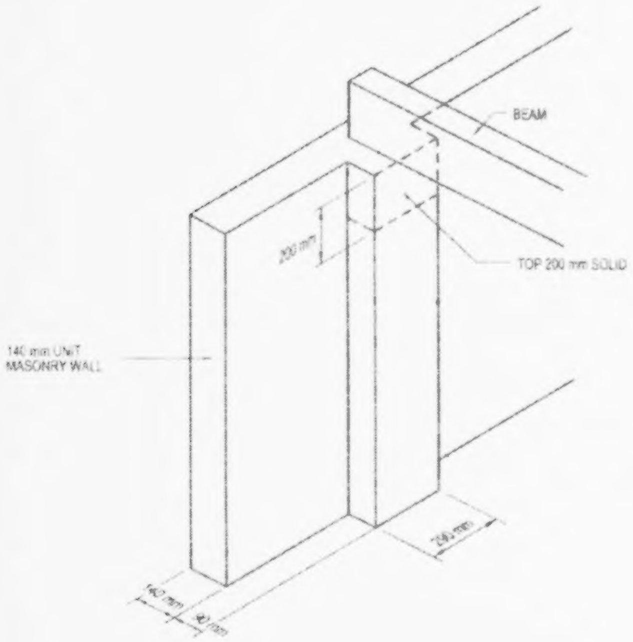

BEAM
200 mm
TOP 200 mm SOLID
140 mm UNIT
MASONRY WALL
240 mm
140 mm
90 mm

Figure 12:11
Beam Bearing on Masonry Pilaster – Article 9.15.5.3

EXERCISE #12-4

Read Subsection 9.15.5 and review Figures 12:10 and 12:11. Answer the following questions, then discuss your answers with your group.

1. A floor beam is to be supported on a 190 mm masonry wall. Which of the following is a minimum requirement for proper installation?

    a) A pilaster shall be provided.

    b) The portion of the foundation wall below the beam bearing to be grouted solid for the full height of the wall.

    c) Wall to be capped with a minimum of 50 mm of solid masonry.

    d) 190 mm of solid masonry be provided beneath the beam.

    OBC Reference(s): ________________

STOP

12.7 BRICK ANCHORAGE

The attachment of a brick masonry veneer to masonry, concrete or wood-framing backup is required to ensure that the masonry veneer is properly supported throughout its height. Article 9.20.9.5 of the Code provides minimum requirements for the properties for brick masonry anchorages, including maximum horizontal and vertical spacing of these anchorages. Figure 12:12 illustrates some common types of brick anchorage.

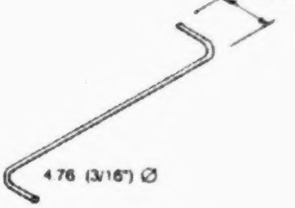

50 (2")
4.76 (3/16") Ø

FIGURE 1
STANDARD Z-WIRE TIE

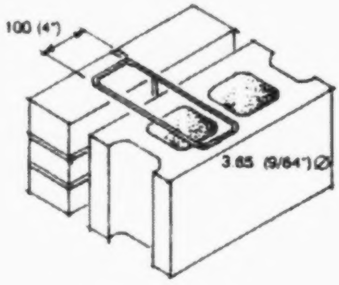

100 (4")
3.65 (9/64") Ø

FIGURE 2
STANDARD RECTANGULAR WIRE TIE

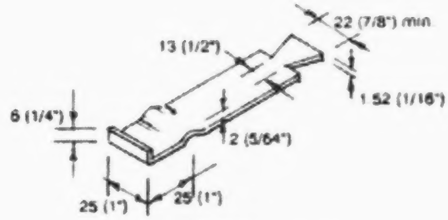

22 (7/8") min.
13 (1/2")
1.52 (1/16")
6 (1/4")
2 (5/64")
25 (1")
25 (1")

FIGURE 3
STANDARD DOVETAIL ANCHOR

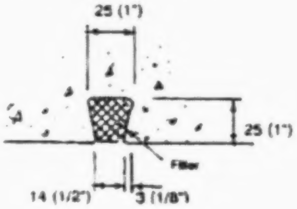

25 (1")
25 (1")
Filler
14 (1/2")
3 (1/8")

FIGURE 4
STANDARD DOVETAIL SLOT

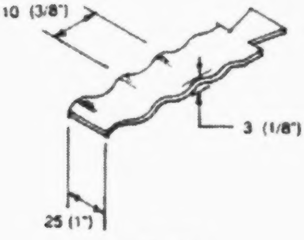

10 (3/8")
3 (1/8")
25 (1")

FIGURE 5
STANDARD CORRUGATED DOVETAIL ANCHOR

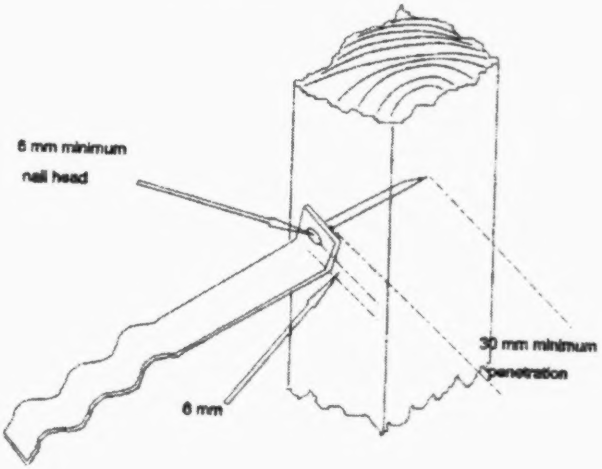

6 mm minimum
nail head
30 mm minimum
penetration
6 mm

Figure 12:12
Typical Brick Anchorages

Exercise #12-5

Read Articles 9.20.9.5 and 9.15.4.7.
Answer the following questions, then discuss your answers with your group.

1. Under what conditions is it necessary to design the anchorage of masonry veneer in conformance with Part 4?

   ____

   ____

   OBC Reference(s): ________________

2. Where the top of a *foundation* wall is reduced in thickness to permit the installation of masonry veneer what is the maximum horizontal and vertical spacing permitted for metal ties?

   a) 400 mm H x 800 mm V
   b) 500 mm H x 600 mm V
   c) 600 mm H x 400 mm V
   d) 900 mm H x 200 mm V

   OBC Reference(s): ________________

STOP

12.8 FINISHING

Foundation walls require finishing to provide a base for waterproofing or dampproofing or above grade a final protective finish.

Parging is when a rough coat of mortar is applied over a masonry wall as protection or finish; it may also serve as a base for an asphaltic dampproofing compound below grade.

Subsection 9.15.6 of the Code provides requirements for finishing of concrete and masonry *foundation* walls.

For below-grade masonry walls, the minimum requirement is for parging on the exterior face, as outlined in Section 9.13. Masonry *foundation* walls above grade are to have tooled joints, parged or otherwise suitably finished.

Concrete *foundation* walls are to have all form ties removed flush to the concrete surface. It is common for small spalls of concrete to be broken from the surface of fresh concrete when the concrete ties are being removed. These spalls should be filled with an asphaltic dampproofing compound, below grade, and mortared above grade, to prevent water infiltration through the points of the form ties.

STOP End of Module 12

MODULE 13

ROOF AND CEILING CONSTRUCTION PART 9 BUILDINGS

BUILDING STRUCTURAL – 2006

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13.0 Introduction 1
13.1 Objectives 1
13.2 Roof Terminology and Definitions 2
13.3 Types of Roof Framing 3
13.4 Limitations of Span Tables 10
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13.6 Roof Sheathing 15
13.7 Fasteners 17
13.8 Connections at Fire Separations 19

13.0 INTRODUCTION

In this Module, we will learn the Code requirements for roof and ceiling construction, for buildings that are designed using Part 9 of the Building Code.

13.1 OBJECTIVES

Upon completion of this Module, participants will be able to:

- Recognize the limitations of the member selection methods of Section 9.23, and when Part 4 applies
- Identify specific words and terminology pertaining to wood-framed construction, and identify important construction components
- Identify the types of structural framing that may be designed under Section 9.23
- Select the spans of members using Part 9 tables
- Recognize the special provisions for heavy roofs and special roofing systems
- Recognize bridging requirements and be able to select bridging for joists
- Select roof sheathing
- Recognize bracing, fastening, and nailing requirements for conventional roof framing
- Recognize the importance of bearing and bracing of trusses, and know where to find the requirements
- Identify the importance of connections made at fire separations

13.2 ROOF TERMINOLOGY AND DEFINITIONS

For a glossary of terms relevant to roof and ceiling construction, refer to:

- Canadian Wood-frame House Construction, by the Canada Mortgage and Housing Corporation (CMHC) – illustrations and glossary.
- The Span Book, by The Canadian Wood Council

There are many other references that can be helpful in becoming familiar with the terminology for wood construction. Familiarity with these terms is essential for a good understanding of construction principles and practices. As a minimum you should be familiar with the following:

- Beam
- Bearing
- Bearing Wall
- Bottom chord, top chord, and web members
- Bridging
- Collar tie
- Cottage roof
- Dead Load and Live Load
- Dormer
- Dwarf wall (kneewall)
- Gable
- Gable Roof
- Girder truss and Common Truss
- Grade (lumber)
- Gussets
- Header and Trimmer
- Hip
- Hip rafter
- Jack rafter
- Jack truss
- Joist
- Joist hanger
- Ledger strip
- Lintel
- Loadbearing
- Lookout rafter
- On Centre (oc)
- Panel
- Partition
- Pier
- Pilaster
- Pitch
- Pitched Roof
- Rafter
- Ribbon board
- Ridge beam
- Ridge board
- Shed roof
- Span
- Strut
- Stud
- Top plate
- Truss
- Valley
- Valley rafter
- Wall plates
- Wall tie
- Web

If you have any questions about the meaning of these terms discuss them with your group.

13.3 TYPES OF ROOF FRAMING

There are two basic types of wood roof framing. Conventional roof framing, which we will discuss in detail here, and Truss roof framing. Conventional framing is also known as 'stick framing', as the structure is assembled on site from a number of individual pieces of wood.

Conventional roof framing for sloped roof construction consists of a simple triangle. Figure 13:1 shows this simple case plus some variations. The variations show methods of reducing the span of the roof joist with use of a collar tie, diagonal braces or dwarf walls. Beyond the design of the members for the roof framing, attention must be given to the connections. The tension connections provided at heel joints and ceiling joist splices are the most critical joints in this type of construction.

In cases where there are secondary members that transfer loads to the ceiling joists, it is important to include these loads when sizing the ceiling joist members. It is also important to know whether the ceiling joist was designed to support the load, or whether it is to be transferred to an interior partition wall, in which case the interior partition wall becomes *loadbearing* and therefore requires appropriate attention.

Subsection 9.23.13 provides Code requirements for roof and ceiling framing.

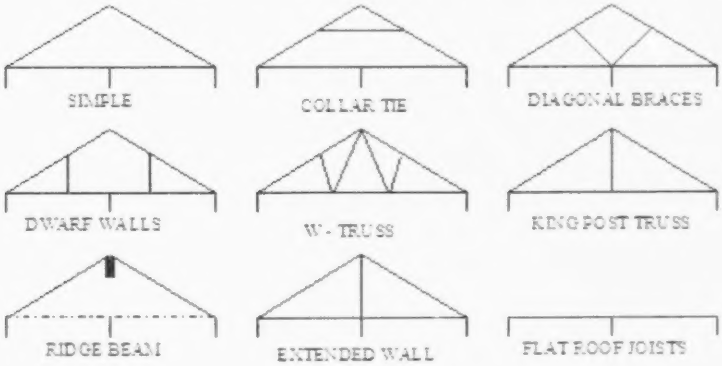


Figure 13:1
Typical Roof Framing

EXERCISE #13-1

Review Subsection 9.23.13 while making reference to Figures 13:2 to 13:7.
Complete the following exercise, then discuss the answers with the group.

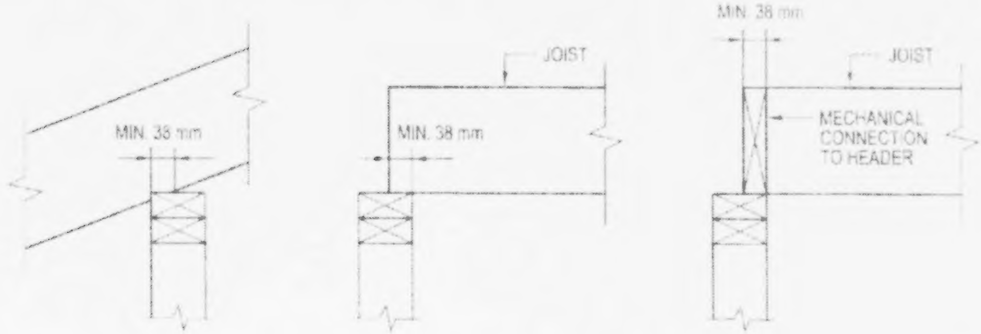

MIN. 38 mm
JOIST
MIN. 38 mm
MIN. 38 mm
JOIST
MECHANICAL CONNECTION TO HEADER

Figure 13:2
Joist Bearing – Sentence 9.23.13. 3.(1)

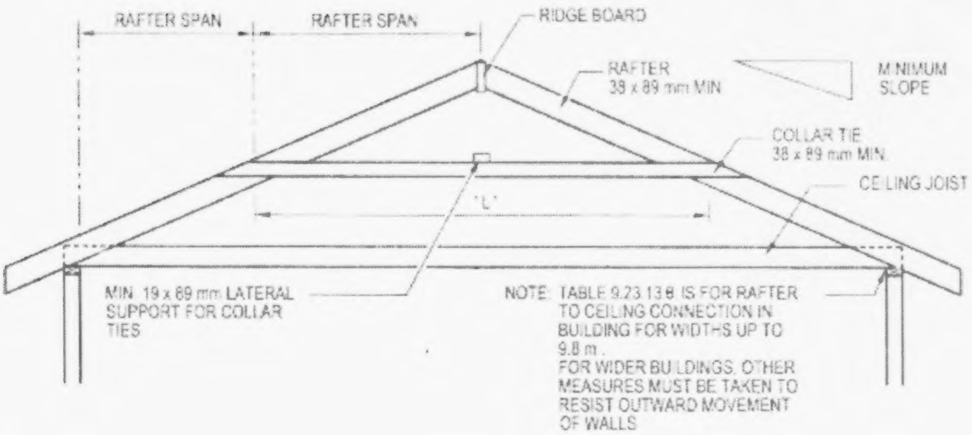

RAFTER SPAN
RAFTER SPAN
RIDGE BOARD
RAFTER 38 x 89 mm MIN
MINIMUM SLOPE
COLLAR TIE 38 x 89 mm MIN.
CEILING JOIST
"L"
MIN. 19 x 89 mm LATERAL SUPPORT FOR COLLAR TIES
NOTE: TABLE 9.23.13.8 IS FOR RAFTER TO CEILING CONNECTION IN BUILDING FOR WIDTHS UP TO 9.8 m.
FOR WIDER BUILDINGS, OTHER MEASURES MUST BE TAKEN TO RESIST OUTWARD MOVEMENT OF WALLS

Figure 13:3
Intermediate Support - Collar Tie – Sentence 9.23.13.7.(2)

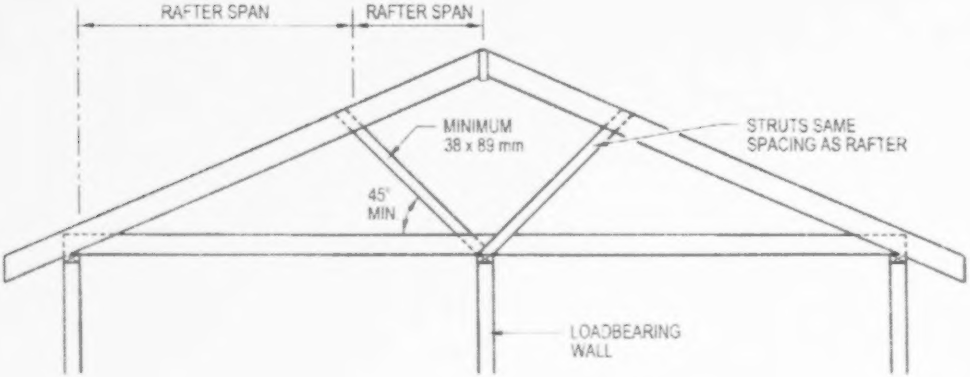

RAFTER SPAN
RAFTER SPAN
MINIMUM 38 x 89 mm
STRUTS SAME SPACING AS RAFTER
45° MIN
LOADBEARING WALL

Figure 13:4
Intermediate Support – Diagonal Braces – Sentence 9.23.13.7.(4)

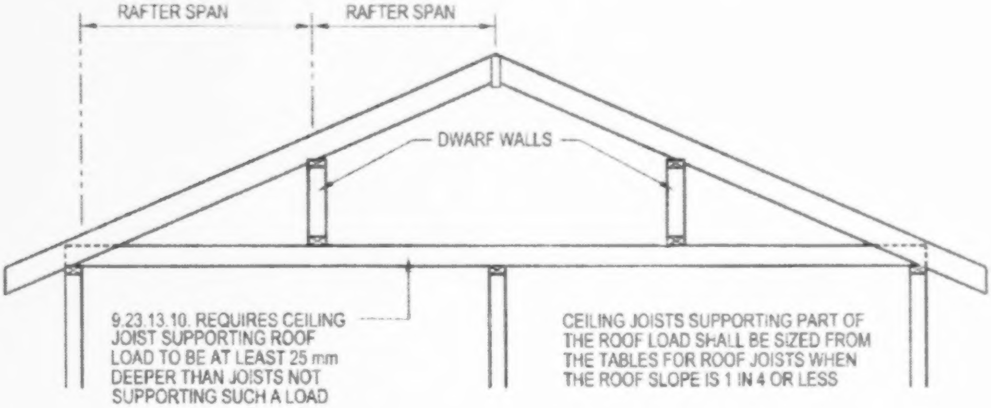
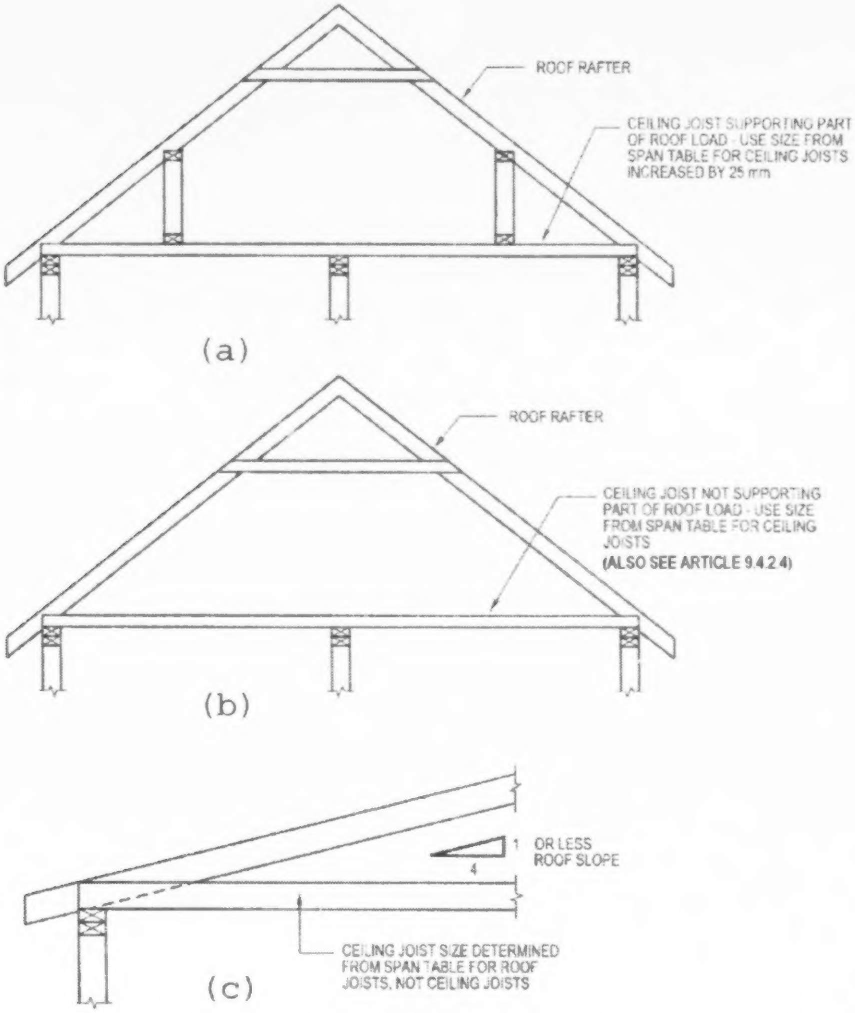

RAFTER SPAN
RAFTER SPAN
DWARF WALLS
9.23.13.10. REQUIRES CEILING JOIST SUPPORTING ROOF LOAD TO BE AT LEAST 25 mm DEEPER THAN JOISTS NOT SUPPORTING SUCH A LOAD
CEILING JOISTS SUPPORTING PART OF THE ROOF LOAD SHALL BE SIZED FROM THE TABLES FOR ROOF JOISTS WHEN THE ROOF SLOPE IS 1 IN 4 OR LESS

Figure 13:5
Intermediate Support – Dwarf Walls – Article 9.23.13.7.7.(3)


ROOF RAFTER
CEILING JOIST SUPPORTING PART OF ROOF LOAD - USE SIZE FROM SPAN TABLE FOR CEILING JOISTS INCREASED BY 25 mm
ROOF RAFTER
CEILING JOIST NOT SUPPORTING PART OF ROOF LOAD - USE SIZE FROM SPAN TABLE FOR CEILING JOISTS
(ALSO SEE ARTICLE 9.4.2.4)
1
4
OR LESS ROOF SLOPE
CEILING JOIST SIZE DETERMINED FROM SPAN TABLE FOR ROOF JOISTS, NOT CEILING JOISTS

(a)

(b)

(c)

Figure 13:6
Ceiling Joists Supporting Loads – Article 9.23.13.10

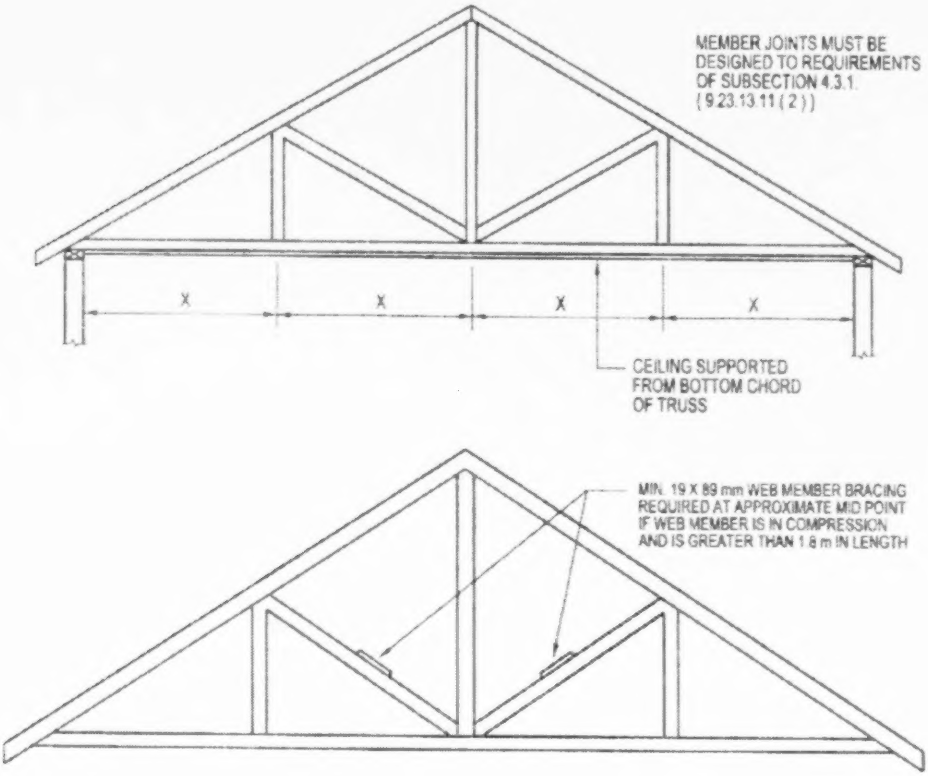

MEMBER JOINTS MUST BE DESIGNED TO REQUIREMENTS OF SUBSECTION 4.3.1. (9.23.13.11 (2))
X
X
X
X
CEILING SUPPORTED FROM BOTTOM CHORD OF TRUSS
MIN. 19 X 89 mm WEB MEMBER BRACING REQUIRED AT APPROXIMATE MID POINT IF WEB MEMBER IS IN COMPRESSION AND IS GREATER THAN 1.8 m IN LENGTH

Figure 13:7
Wood Roof Trusses – Article 9.23.13.11

1. When it is necessary to splice a roof rafter, a roof joist, or a ceiling joist, how must the splices be made?
   - a) Using metal gusset plates, designed under Part 4.
   - b) With a minimum of 5 through nails on each side of the splice.
   - c) Over a location of a vertical support.
   - d) Over a location of a vertical support that extends to a location of suitable bearing.

OBC Reference(s): ______________

2. What is minimum length of an end bearing for:
   a) Ceiling joist on an interior wood stud wall?
   _____ mm
   b) Roof rafter on an exterior wood stud wall?
   _____ mm
   c) Roof joist on a *loadbearing* masonry wall?
   _____ mm

OBC Reference(s): ____________________

3. What is the minimum thickness for the ridge board shown in Figure 13:4 if the rafters on each side of the ridge are offset by the member thickness?
   a) 12.5 mm
   b) 17.5 mm
   c) 19.0 mm
   d) 38.0 mm

OBC Reference(s): _______________

4. Must the ridge board in Question 3 be designed as a beam if the roof slope is 1:4?

Yes ☐ No ☐

Why? __________________________

____

OBC Reference(s): _______________

5. What is the minimum roof slope that the collar tie in Figure 13:3 can be used to reduce the rafter span as shown? (Note: Choices shown as Rise:Run)
   a) 1:2
   b) 1:3
   c) 1:4
   d) 5:12

OBC Reference(s): _______________

6. If the collar tie shown in Figure 13:3 is only 2450 mm long, is the additional lateral support shown necessary?

   Yes ☐ No ☐

   OBC Reference(s): ______________

7. What structural requirements are not indicated in Figure 13:5 if the space created by the dwarf walls is to be a finished space?

   ____

   ____

   ____

   OBC Reference(s): ______________

8. A full size model of a wooden roof truss (4.5m span) has passed a load test in conformance with CSA S307-M and was capable of supporting a ceiling load of 0.35 kPa plus a roof load of 5.4 kPa for 24 hours. Assuming that the truss passed the test for deflection as specified in Clause 9.23.13.11.(1)(b), what is the maximum specified roof snow load (S) that the truss would be able to be used for?

   a) 5.4 kPa

   b) 2.7 kPa

   c) 4.1 kPa

   d) 2.0 kPa

   OBC Reference(s): ______________

STOP

13.4 LIMITATIONS OF SPAN TABLES

As with all sections of Part 9, there are limitations or certain conditions that must be met before being able to apply the provisions in the Code.

Limitations regarding the protection of structural framing from decay, termites, and dampness are found in Subsection 9.23.2. These limitations express the importance of proper *vapour barrier* and building envelope details to protect the structural framing from being damaged.

However, the limitations that are discussed here are with respect to the span tables located at the end of Part 9 for determining the required size and spacing of rafters, joists, and ceiling joists. There are four main areas that provide limitations on the use of the span tables, Articles 9.23.1.1, 9.23.4.1, 9.23.4.4, and 9.23.4.5.

Exercise #13-2

Read Subsections 9.23.1, 9.23.2, and Articles 9.23.4.1, 9.23.4.4 and 9.23.4.5.
Answer the following questions, then discuss your answers with your group.

1. How must a wood structural member, which frames into a masonry column below *grade*, be prevented from decay?

    ____

    ____

    ____

    ____

    ____

    OBC Reference(s): ________________

2. What is the maximum design *live load* for floor system in a conventional wood framed building that would allow design of the floors using Section 9.23?

   a) 2.4 kPa

   b) 1.4 kPa

   c) 1.9 kPa

   d) 4.8 kPa

OBC Reference(s): ______________

3. Considering Article 9.23.4.1 for residential areas, what is the maximum listed uniform distributed *live load* that can be used when determining the maximum member span supporting a floor for a Part 9 *building*?

   a) 1.4 kPa

   b) 1.9 kPa

   c) 2.4 kPa

   d) 4.8 kPa

OBC Reference(s): ______________

4. Which of the following is not a condition that would allow the use of the Table A-2 for joist spans for a floor supporting a concrete topping?

   a) Concrete topping is 38 mm thick

   b) Normal weight concrete is specified.

   c) Concrete placed on a polyethylene sheet to protect the subfloor from moisture.

   d) Concrete specified to have a 20 MPa compressive strength after 28 days.

OBC Reference(s): ______________

STOP

13.5 THE USE OF SPAN TABLES

Span tables simplify the design or selection of member sizes for joists, rafters, and beams.
Tables A-1 to A-12 describe maximum spans allowed for ceiling, floor, and roof joists, including roof ridge beams and built-up wood and glue laminated timber floor beams.
Maximum spans for laterally supported steel beams meeting the minimum requirements for Grade 350W steel in CAN/CSA-G40.21 can be found in Table 9.23.4.3.

For the purposes of these span tables, the span is measured from the inside face or edge of support to inside face or edge of support. In the case of sloping members, the span is measured as the horizontal distance between supports and **not** the sloping distance. Figures 13:4 and 13:5 provide examples of this horizontal span distance for sloping members.

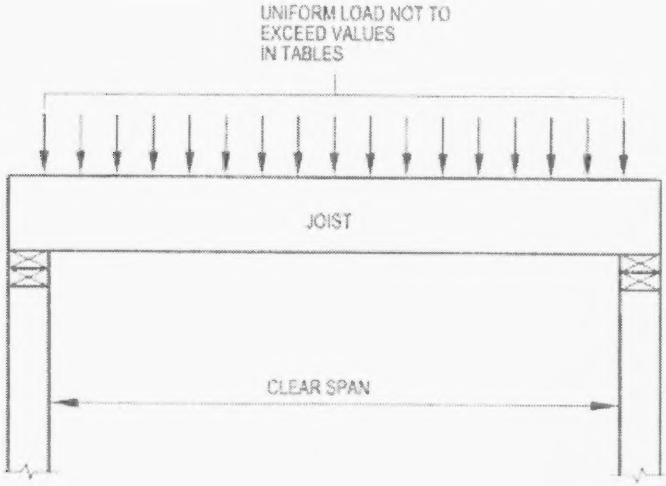


Figure 13:8
Span Measurement for Tables A-1 to A-12

Exercise #13-3

Read Articles 9.23.4.2, 9.23.4.3 and familiarize yourself with Tables A-1 to A-12 from Part 9.
Answer the following questions, then discuss your answers with your group.

1. Given the following set of conditions:

   - Specified roof snow load (S) of 1.5 kPa
   - Lumber is No.2 grade SPF
   - Span is 5200 mm
   - Ceiling finish is Gypsum board
   - No concentrated loads

   Which of the following construction would not be acceptable for the given roof joist loading above?

   a) 38x235 spaced at 300 mm.

   b) 38x286 spaced at 300 mm.

   c) 38x235 spaced at 400 mm.

   d) 38x286 spaced at 400 mm.

   OBC Reference(s): ________________

2. Refer to Figure 13:3.
   Assume that the collar tie divides the rafter span equally and the clear span of the roof is 8.4 metres, and the roof slope is 1:3.
   The specified roof snow load is 2.0 kPa.
   Lumber is No. 1 SPF.

   What is the minimum permitted size and spacing of rafter?

   a) 38x89 spaced at 400 mm.

   b) 38x184 spaced at 400 mm.

   c) 38x235 spaced at 300 mm.

   d) Outside limit of Table

   OBC Reference(s): ________________

3. For the framing in Question 2 above, what is the minimum permitted size and spacing of rafter without the collar ties?
   a) 38x89 spaced at 400 mm.
   b) 38x184 spaced at 400 mm.
   c) 38x235 spaced at 300 mm.
   d) Outside limit of Table

   OBC Reference(s): ________________

4. Refer to Figure 13:6 (b).
   Assume the ceiling joist shown is supported by the partition at the centre of the room. The roof clear span is 8.4 metres. The ceiling supports a gypsum board finish and the space above is not accessible by a stairway. Lumber is No.1 SPF.
   Which of the following is the minimum permitted size and spacing of the ceiling joist?
   a) 38x140 spaced at 400 mm.
   b) 38x184 spaced at 400 mm.
   c) 38x235 spaced at 400 mm.
   d) 38x286 spaced at 400 mm.

   OBC Reference(s): ________________

5. If the ceiling joists in Question 4 above were to support knee walls, what would be their minimum size?
   a) If roof slope is greater than 1:4 (Rise:Run)?
      i. 38x140 spaced at 400 mm.
      ii. 38x184 spaced at 400 mm.
      iii. 38x235 spaced at 400 mm.
      iv. 38x286 spaced at 300 mm.

   OBC Reference (s): ________________

Question 5 - Continued.

b) If roof slope is 1:4 or less with a specified roof snow load of 1.5 kPa and lumber grade is SPF No.1?

  i. 38x140 spaced at 400 mm.
  ii. 38x184 spaced at 400 mm.
  iii. 38x235 spaced at 400 mm.
  iv. 38x286 spaced at 300 mm.

OBC Reference(s): ________________

6. What would be the required built-up ridge beam size for a roof required to span 3.5 m between supports, where the specified snow load is 2.0kPa?
Consider SPF No.1 grade lumber. The supported length of the ridge beam is 4.4 m.

  a) 4-38 spaced at 235 mm.
  b) 5-38 spaced at 235 mm.
  c) 3-38 spaced at 286 mm.
  d) 4-38 spaced at 286 mm.

OBC Reference(s): ________________

STOP

13.6 ROOF SHEATHING

Once the roof rafters or trusses are in place and properly braced, roof sheathing is then added. The roof sheathing ties the framing together, transfers gravity loads from the roofing system to the rafters or joists, and forms a diaphragm that transfers lateral loads to the vertical supporting structure below. The roof sheathing usually consists of plywood or waferboard. In order for the roof sheathing to properly form the diaphragm, it needs to be properly attached to the framing members.

Part 9 has provided, in Subsection 9.23.15, the requirements to satisfy the creation of this diaphragm for *buildings* that conform to Part 9.

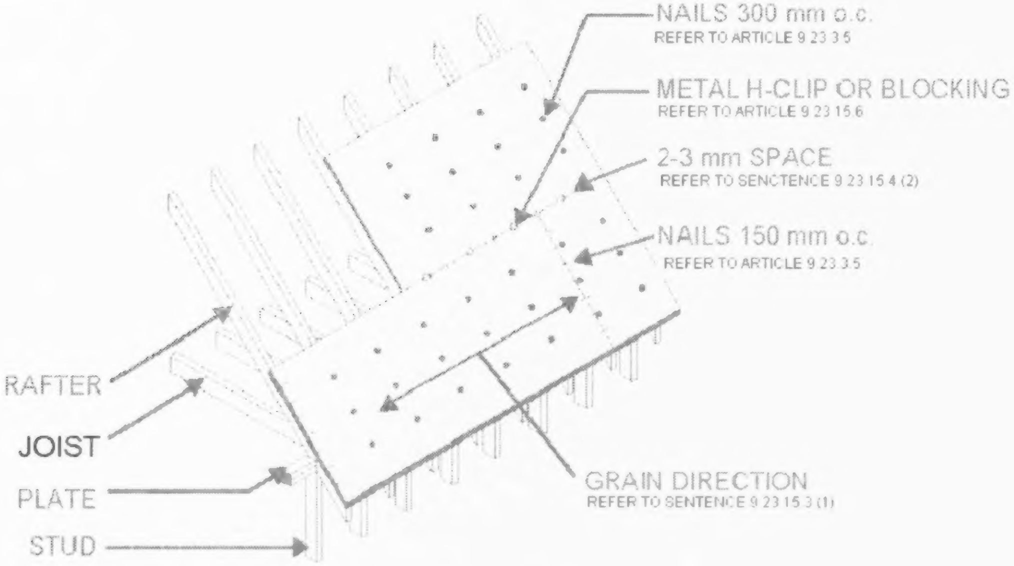

NAILS 300 mm o.c.
REFER TO ARTICLE 9.23.3.5
METAL H-CLIP OR BLOCKING
REFER TO ARTICLE 9.23.15.6
2-3 mm SPACE
REFER TO SENCTENCE 9.23.15.4.(2)
NAILS 150 mm o.c.
REFER TO ARTICLE 9.23.3.5
RAFTER
JOIST
PLATE
STUD
GRAIN DIRECTION
REFER TO SENTENCE 9.23.15.3.(1)

Figure 13:9
Roof Sheathing – Article 9.23.15

EXERCISE #13-4

Read Subsection 9.23.15 and review Figure 13:9.
Answer the following questions, then discuss your answers with your group.

1. Which of the following is not a permissible method of providing edge support for panel type roof sheathing?
   a) Provide metal H clips
   b) Provide 38 mm x 38 mm blocking
   c) Provide tongue and groove edged panels
   d) Provide a continuous bead of construction adhesive on panel edges.

   OBC Reference(s): ________________

2. Roof joists are spaced at 600 mm on centre, and a 9.5 mm thick plywood panel is to be used for roof sheathing on a flat roof.
   What additional requirement(s) must be made to properly install this paneling?
   a) Roof not used as a walking deck.
   b) Roof not used as a walking deck and panel edges must be supported.
   c) Panel edges must be supported.
   d) No additional requirements.

OBC Reference(s): ______________

STOP

13.7 FASTENERS

In order to hold all the lumber together, and to have it then act as a structural system, more than just a good fit of the joints is needed. Fasteners are necessary to resist forces other than gravity loads (such as roof uplift) and to maintain stability of the structure.

Subsection 9.23.3 of the Code provides the requirements that fasteners must meet, plus a minimum number and size of fasteners for attaching various framing members and sheathing together.

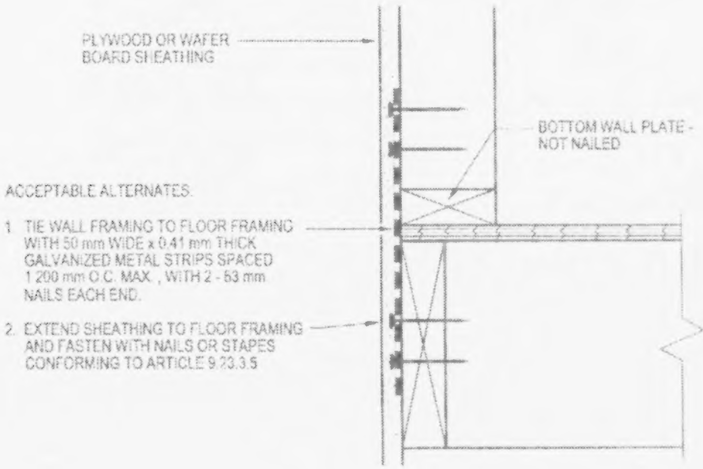

PLYWOOD OR WAFER BOARD SHEATHING
BOTTOM WALL PLATE - NOT NAILED
ACCEPTABLE ALTERNATES:
1. TIE WALL FRAMING TO FLOOR FRAMING WITH 50 mm WIDE x 0.41 mm THICK GALVANIZED METAL STRIPS SPACED 1 200 mm O.C. MAX., WITH 2 - 63 mm NAILS EACH END.
2. EXTEND SHEATHING TO FLOOR FRAMING AND FASTEN WITH NAILS OR STAPES CONFORMING TO ARTICLE 9.23.3.5

Figure 13:10
Wall Framing Attachment Alternatives

Exercise #13-5

Read Subsection 9.23.3. Answer the following questions, then discuss the answers with the group.

1. What is the minimum number and length of nails required to fasten a rafter to a collar tie?
   - a) 3 – 76 mm Nails each end
   - b) 2 – 76 mm Nails each end
   - c) 2 – 57 mm Nails each end
   - d) 3 – 57 mm Nails each end

   OBC Reference(s): ____________

STOP

13.8 CONNECTIONS AT FIRE SEPARATIONS

When a *fire separation* between units is required, the use of *combustible* or *noncombustible* construction of the fire separation can affect the details of members supported on the *fire separation*. If using *noncombustible* materials for the *fire separation* and *combustible* members frame into the separation, Subsection 9.10.9.8 of the Code requires that they must be attached so that, if they collapse due to fire, they do not cause the collapse of the *fire separation*.

Figure 13:11 shows a detail where a 'Fire Cut' has been made in the block wall so that the floor joist shown can freely rotate without putting a concentrated moment on the wall that could cause its failure. What the figure does not show however is that the wall's unbraced height has just increased and may cause the wall to become unstable.

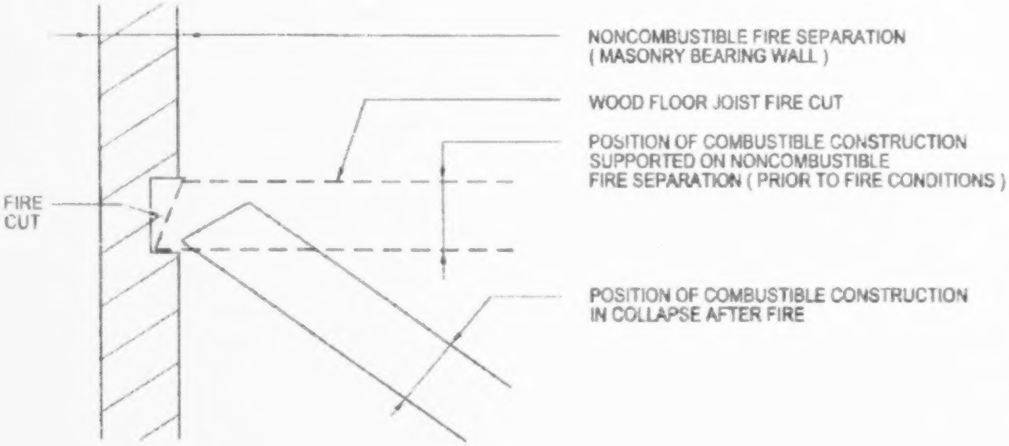

NONCOMBUSTIBLE FIRE SEPARATION
(MASONRY BEARING WALL)
WOOD FLOOR JOIST FIRE CUT
POSITION OF COMBUSTIBLE CONSTRUCTION
SUPPORTED ON NONCOMBUSTIBLE
FIRE SEPARATION (PRIOR TO FIRE CONDITIONS)
FIRE
CUT
POSITION OF COMBUSTIBLE CONSTRUCTION
IN COLLAPSE AFTER FIRE

Figure 13:11
Special Consideration at Fire Separations and Combustible Construction

STOP End Of Module 13

MODULE 14

FLOOR CONSTRUCTION – PART 9 BUILDINGS

BUILDING STRUCTURAL – 2006

TABLE OF CONTENTS

14.0 Introduction 1
14.1 Objectives 1
14.2 Anchorage, Bearing and Bridging of Floor Framing 1
14.3 Span Tables for Beams and Floor Joists 10
14.4 Subflooring 20
14.5 Engineered Floor Systems 22

14.0 INTRODUCTION

In this Module, we will learn the requirements for floor construction as it relates to the construction of *buildings* that conform to Part 9.

14.1 OBJECTIVES

Upon completion of this Module, participants will be able to:

- Recognize the limitations of the member selection methods of Part 9, and when Part 4 applies
- Review specific words and terminology pertaining to wood-framed construction, and identify important construction components
- Determine spans of joists and beam members using Part 9 tables, including cantilevers and concentrated loads
- Select framing at openings
- Select floor sheathing
- Identify anchorage, bearing and strapping/bridging requirements
- Relate the code requirements for manufactured or engineered floor system products (i.e., wood I beams)

14.2 ANCHORAGE, BEARING AND BRIDGING OF FLOOR FRAMING

The frames of *buildings* must be anchored to the building *foundation* unless structural analysis demonstrates that such anchorage is not necessary. Subsection 9.23.6 provides requirements for such anchorage. Figure 14:1 depicts one acceptable method of such anchorage.

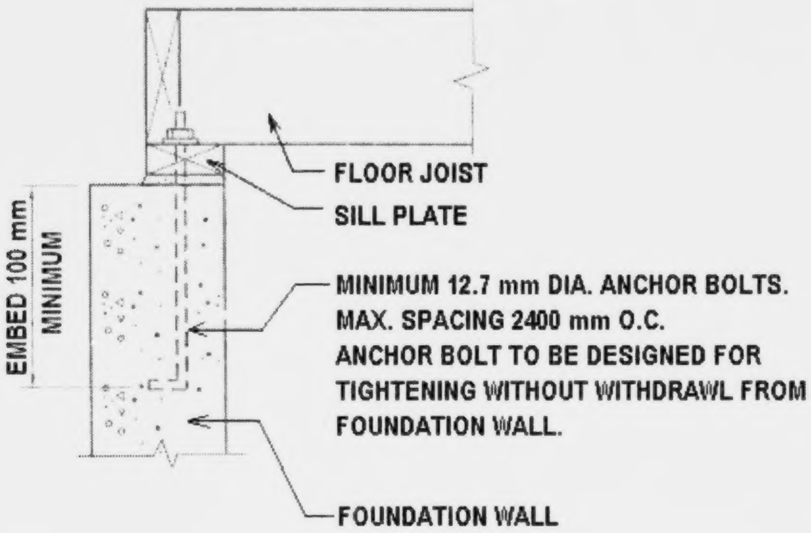

FLOOR JOIST
SILL PLATE
EMBED 100 mm MINIMUM
MINIMUM 12.7 mm DIA. ANCHOR BOLTS. MAX. SPACING 2400 mm O.C. ANCHOR BOLT TO BE DESIGNED FOR TIGHTENING WITHOUT WITHDRAWL FROM FOUNDATION WALL.
FOUNDATION WALL

Figure 14:1
Anchorage of Building Frames - Article 9.23.6.1

The anchorage shown in Figure 14:1 is made through the sill plate of the foundation wall. Subsection 9.23.7 provides requirements for the minimum size of such sill plates and methods for leveling of the sill plates. Figure 14:2 provides a summary of the requirements of this Subsection.

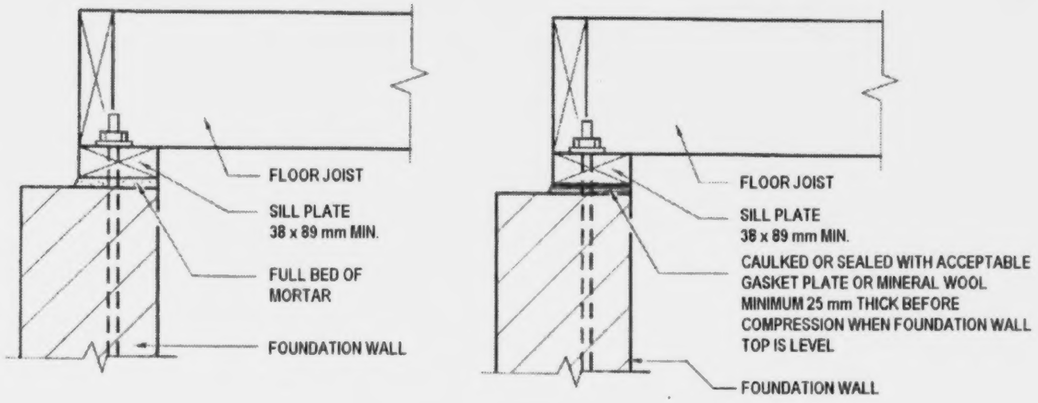

FLOOR JOIST
SILL PLATE
38 x 89 mm MIN.
FULL BED OF
MORTAR
FOUNDATION WALL
FLOOR JOIST
SILL PLATE
38 x 89 mm MIN.
CAULKED OR SEALED WITH ACCEPTABLE
GASKET PLATE OR MINERAL WOOL
MINIMUM 25 mm THICK BEFORE
COMPRESSION WHEN FOUNDATION WALL
TOP IS LEVEL
FOUNDATION WALL

Figure 14:2
Sill Plates - Subsection 9.23.7

The requirements for sill plates include a minimum size when supporting a *loadbearing* floor system.

Figure 14:3 illustrates common simple bearing details that comply with Code requirements for floor joists framing into wood *loadbearing* walls. Figures 14:4, 14:5 and 14:6 show additional framing requirements when wood joists are framed into built up wood beams and steel beams respectively. Refer to Subsection 9.23.9 while reviewing these figures.

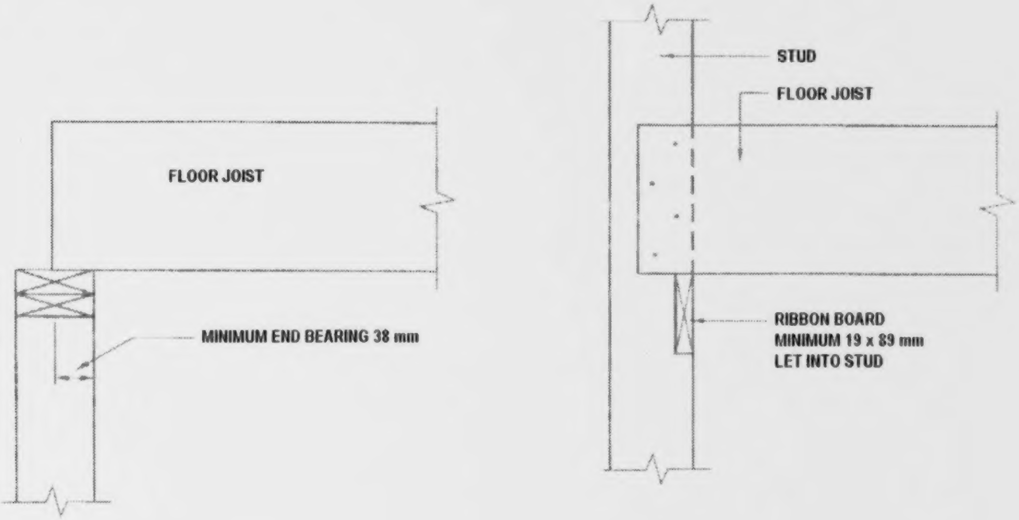

FLOOR JOIST
MINIMUM END BEARING 38 mm
STUD
FLOOR JOIST
RIBBON BOARD
MINIMUM 19 x 89 mm
LET INTO STUD

Figure 14:3
Simple Joist Bearing – Article 9.23.9.1

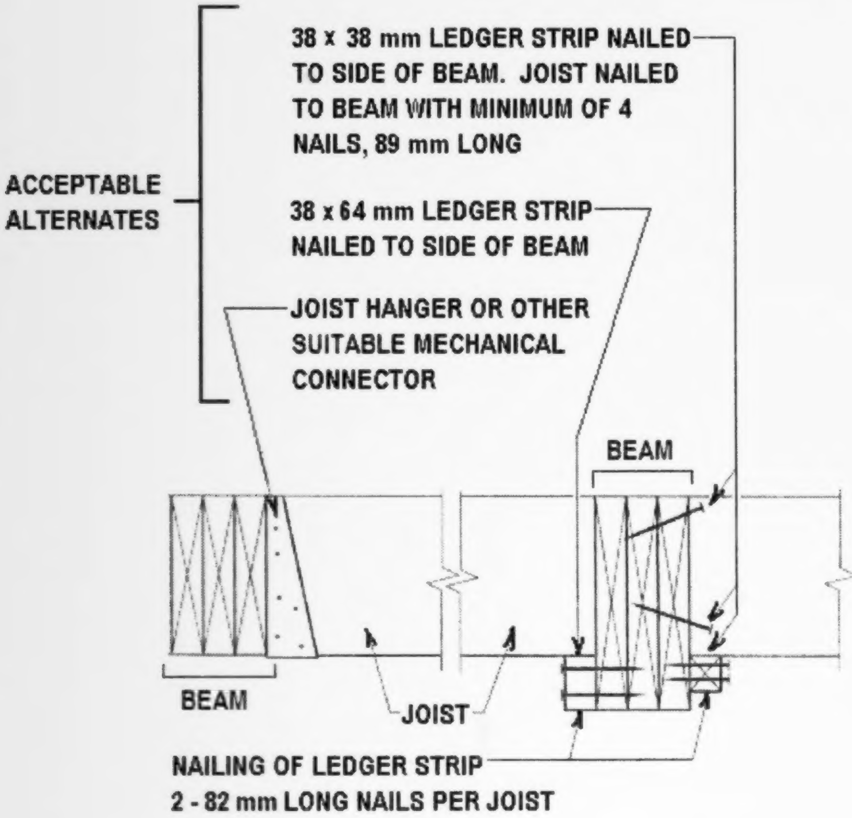

ACCEPTABLE ALTERNATES
38 x 38 mm LEDGER STRIP NAILED TO SIDE OF BEAM. JOIST NAILED TO BEAM WITH MINIMUM OF 4 NAILS, 89 mm LONG
38 x 64 mm LEDGER STRIP NAILED TO SIDE OF BEAM
JOIST HANGER OR OTHER SUITABLE MECHANICAL CONNECTOR
BEAM
BEAM
JOIST
NAILING OF LEDGER STRIP 2 - 82 mm LONG NAILS PER JOIST

Figure 14:4
Joists Support on Built Up Timber Beams - Article 9.23.9.2

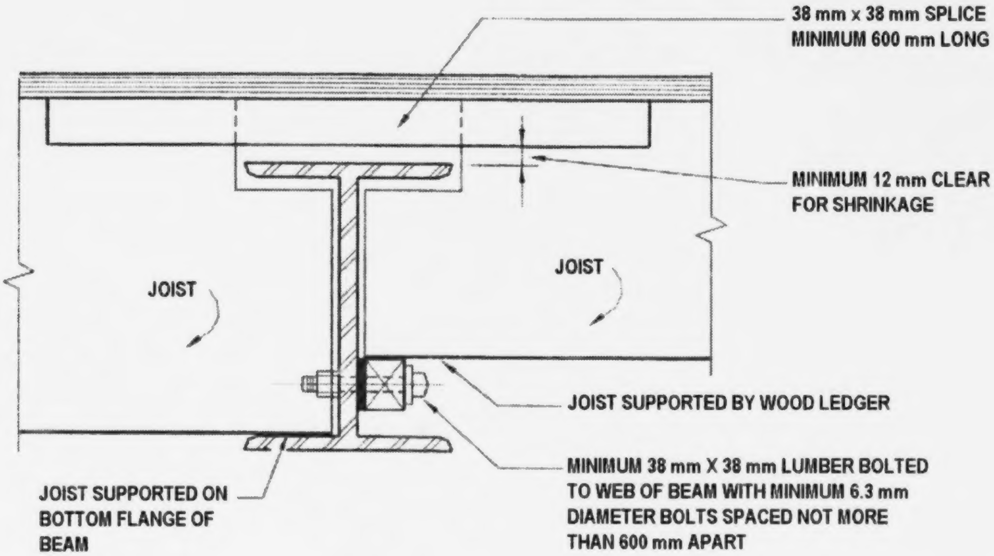

38 mm x 38 mm SPLICE MINIMUM 600 mm LONG
MINIMUM 12 mm CLEAR FOR SHRINKAGE
JOIST
JOIST
JOIST SUPPORTED BY WOOD LEDGER
MINIMUM 38 mm X 38 mm LUMBER BOLTED TO WEB OF BEAM WITH MINIMUM 6.3 mm DIAMETER BOLTS SPACED NOT MORE THAN 600 mm APART
JOIST SUPPORTED ON BOTTOM FLANGE OF BEAM

Figure 14:5
Joists Bearing on Steel Beams – Sentence 9.23.9.2.(3)

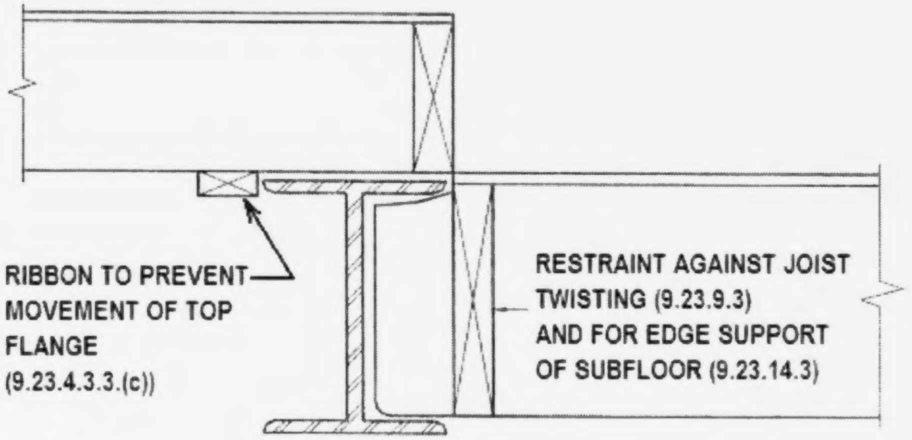

RIBBON TO PREVENT MOVEMENT OF TOP FLANGE (9.23.4.3.3.(c))
RESTRAINT AGAINST JOIST TWISTING (9.23.9.3) AND FOR EDGE SUPPORT OF SUBFLOOR (9.23.14.3)

Figure 14:6
Alternate Joists Bearing on Steel Beams – Sentence 9.23.9.2.(3)

When beams are set to bear on supports they must have a minimum 89 mm even and level bearing as required by Article 9.23.8.1.

An additional requirement for floor joists is that the end of each floor joist is to be restrained from twisting. Figure 14:7 provides acceptable options to provide this restraint of joists.

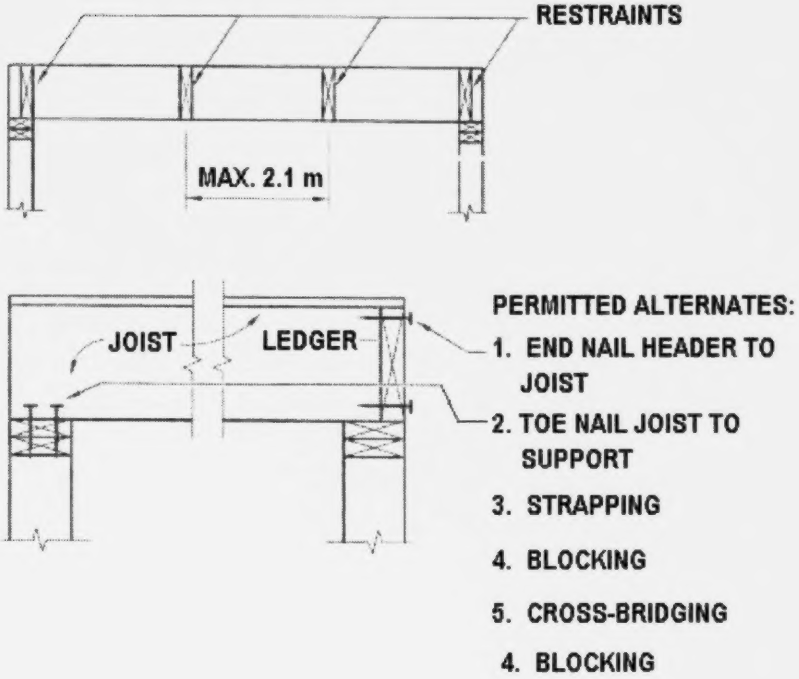

RESTRAINTS
MAX. 2.1 m
JOIST
LEDGER
PERMITTED ALTERNATES:
1. END NAIL HEADER TO JOIST
2. TOE NAIL JOIST TO SUPPORT
3. STRAPPING
4. BLOCKING
5. CROSS-BRIDGING
4. BLOCKING

Figure 14:7
Joist End Restraint – Article 9.23.9.3

Lateral support along the length of the joist allows for longer allowable spans for the floor joists. Article 9.23.9.4 provides the requirements for this bridging and is summarized in Figure 14:8 below.

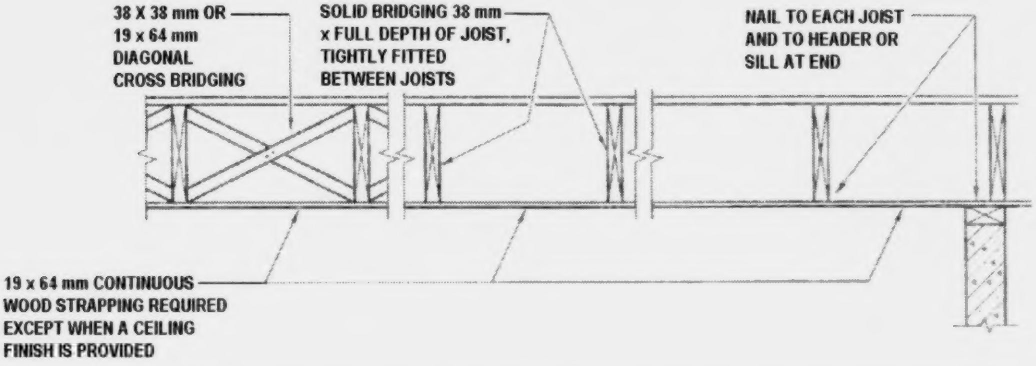

38 X 38 mm OR
19 x 64 mm
DIAGONAL
CROSS BRIDGING
SOLID BRIDGING 38 mm
x FULL DEPTH OF JOIST,
TIGHTLY FITTED
BETWEEN JOISTS
NAIL TO EACH JOIST
AND TO HEADER OR
SILL AT END
19 x 64 mm CONTINUOUS
WOOD STRAPPING REQUIRED
EXCEPT WHEN A CEILING
FINISH IS PROVIDED

Figure 14:8

Bridging and Strapping – Article 9.23.9.4

Exercise #14-1

Read Article 9.23.6.1, Subsection 9.23.7, and Articles 9.23.8.1, 9.23.9.1 to 9.23.9.4.
Answer the following question, then discuss your answers with your group.

1. What is the maximum spacing of floor joist bridging required in Part 9?

   a) 600 mm

   b) 1600 mm

   c) 2100 mm

   d) 2125 mm (7 feet)

   OBC Reference(s): ______________

2. If anchor bolts are used to anchor the building frame in place, what is the required force that the anchor bolts must resist for acceptance?

   a) 10 kN

   b) 100 kN

   c) No requirements are provided in the Building Code.

   d) To be able to be tightened without withdrawing from the concrete.

   OBC Reference(s): ________________

3. Which of the following is not a requirement for a built up wood beam?
   Note: The term member refers to an individual element that makes up the entire built up beam.

   a) Members joined at quarter points shall be continuous over adjacent supports.

   b) Individual members of a built-up beam shall be at least 38 mm in thickness and installed on edge.

   c) Joints made at quarter points of a multi-span built-up beam shall not reduce the effective beam width by more then half.

   d) The individual members shall be glued and nailed together with a double row of nails at least 89 mm long and spaced no more then 450 mm along the length of the member.

   OBC Reference(s): ________________

STOP

14.3 SPAN TABLES FOR BEAMS AND FLOOR JOISTS

In Module 13, the limitations and use of span tables were discussed. In this Module, we will extend that discussion to the use of built up wood beams and floor joists, including cantilevered floor joists, to select the proper member sizes for a given set of conditions.

Subsection 9.23.8 provides the required and necessary conditions for beams that support floors. The requirements for built-up wood beams are listed in Article 9.23.8.3.

The additional requirements when the individual elements of a built-up member are butt jointed together are summarized in Figures 14:9 and 14:10.

Span tables A-8 to A-10 of Part 9 can be used to determine the span requirements for built-up wood beams. Span Table 11 can be used to determine the span requirements for glue-laminated beams. Tables A20-A29 can be used to determine the span requirements for steel beams.

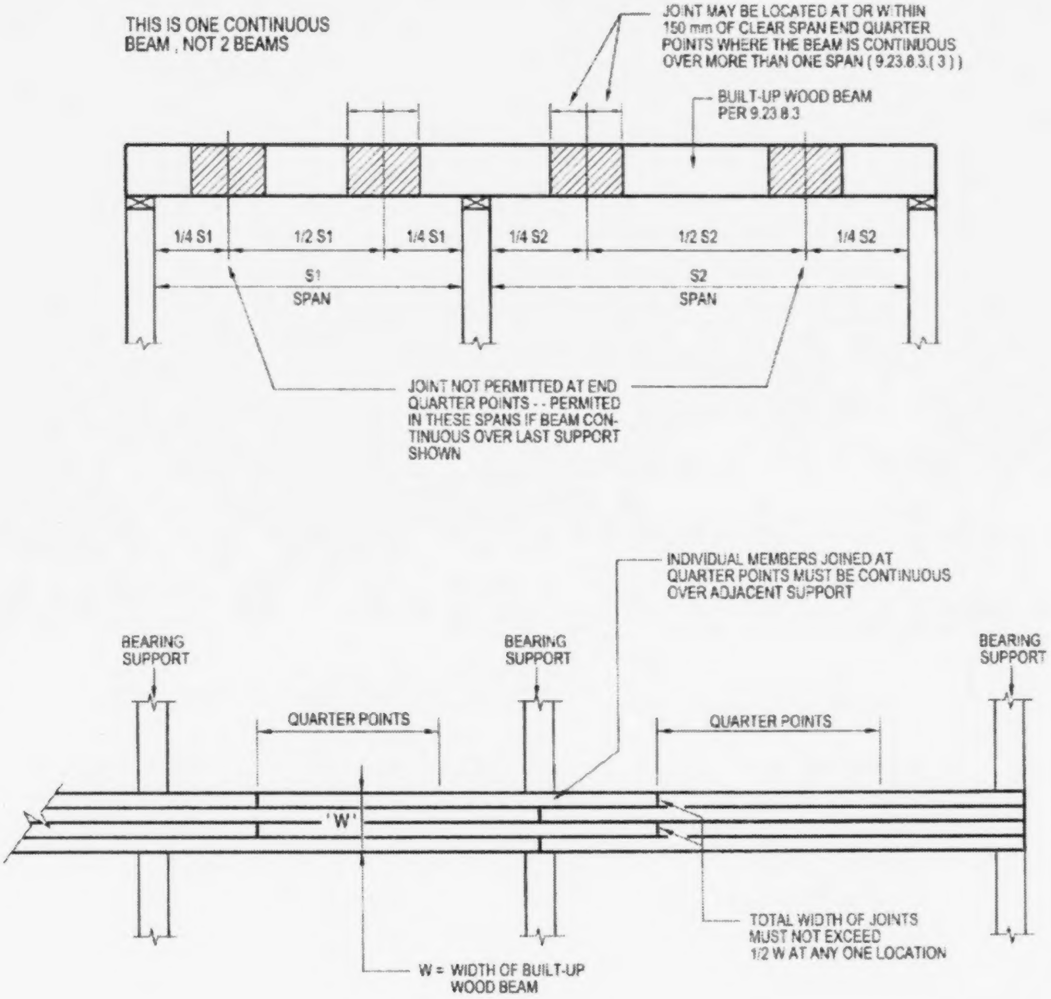

THIS IS ONE CONTINUOUS BEAM , NOT 2 BEAMS
JOINT MAY BE LOCATED AT OR WITHIN 150 mm OF CLEAR SPAN END QUARTER POINTS WHERE THE BEAM IS CONTINUOUS OVER MORE THAN ONE SPAN (9.23.8.3.(3))
BUILT-UP WOOD BEAM PER 9.23.8.3
1/4 S1
1/2 S1
1/4 S1
1/4 S2
1/2 S2
1/4 S2
S1 SPAN
S2 SPAN
JOINT NOT PERMITTED AT END QUARTER POINTS - - PERMITED IN THESE SPANS IF BEAM CONTINUOUS OVER LAST SUPPORT SHOWN
INDIVIDUAL MEMBERS JOINED AT QUARTER POINTS MUST BE CONTINUOUS OVER ADJACENT SUPPORT
BEARING SUPPORT
BEARING SUPPORT
BEARING SUPPORT
QUARTER POINTS
QUARTER POINTS
'W'
TOTAL WIDTH OF JOINTS MUST NOT EXCEED 1/2 W AT ANY ONE LOCATION
W = WIDTH OF BUILT-UP WOOD BEAM

Figure 14:9

Built Up Beams - Joint Locations – Article 9.23.8.3

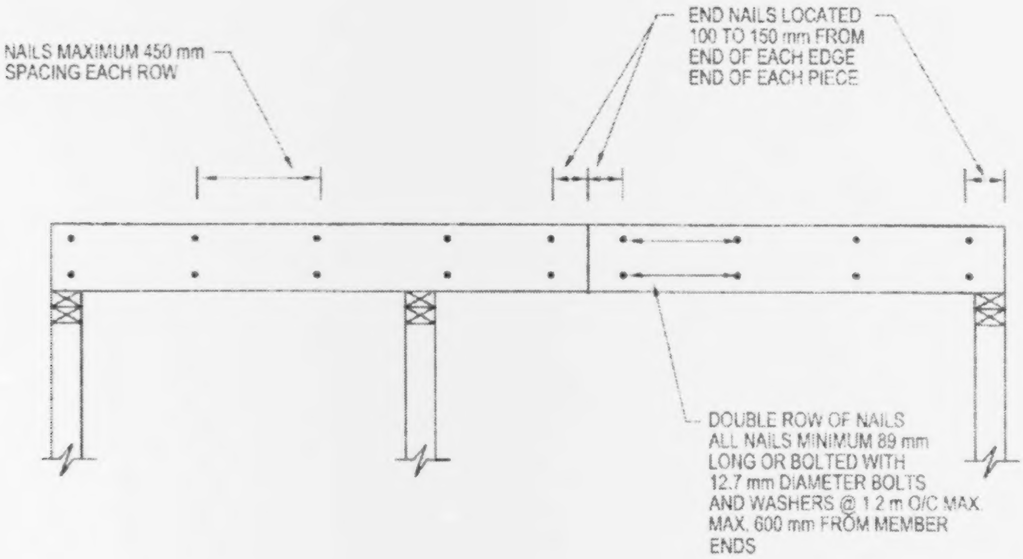

NAILS MAXIMUM 450 mm
SPACING EACH ROW
END NAILS LOCATED
100 TO 150 mm FROM
END OF EACH EDGE
END OF EACH PIECE
DOUBLE ROW OF NAILS
ALL NAILS MINIMUM 89 mm
LONG OR BOLTED WITH
12.7 mm DIAMETER BOLTS
AND WASHERS @ 1.2 m O/C MAX.
MAX. 600 mm FROM MEMBER
ENDS

Figure 14:10

Built Up Beams – Nailing – Article 9.23.8.3

Span Tables A-1 and A-2 of Part 9 are used for the selection of floor joists. This selection is dependent on the presence of bridging, or as in the case of Table A-2, for special conditions of concrete toppings or ceilings attached.

In addition to the routine spacing of joists and their support, a floor must be designed for a number of special conditions. These special conditions include floor openings, support of *loadbearing* and *nonloadbearing* walls, and the use of cantilevered joists.

Special additional framing members around openings are called 'header' and 'trimmer' joists. Their requirements are found in Articles 9.23.9.6 and 9.23.9.7, respectively. Figure 14:11 summarizes these requirements.

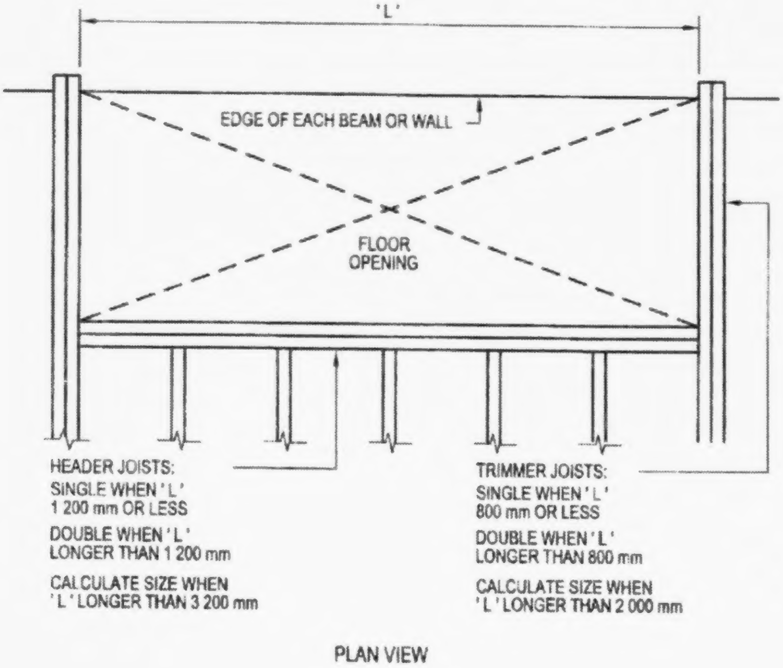

'L'
EDGE OF EACH BEAM OR WALL
FLOOR OPENING
HEADER JOISTS:
SINGLE WHEN 'L' 1 200 mm OR LESS
DOUBLE WHEN 'L' LONGER THAN 1 200 mm
CALCULATE SIZE WHEN 'L' LONGER THAN 3 200 mm
TRIMMER JOISTS:
SINGLE WHEN 'L' 800 mm OR LESS
DOUBLE WHEN 'L' LONGER THAN 800 mm
CALCULATE SIZE WHEN 'L' LONGER THAN 2 000 mm
PLAN VIEW

Figure 14:11
Header and Trimmer Joists

The support of a wall on a floor also requires special framing considerations. The support of a non-*loadbearing* wall on a floor can be either parallel with the floor joists or perpendicular to the floor joists (assuming typical square framed construction).

Non-*loadbearing* walls are not restricted in their location if they are perpendicular to the floor joists. However if a non-*loadbearing* wall runs parallel with the floor joists, then blocking is required between the floor joists below the wall. It is also recommended that if a non-*loadbearing* wall aligns directly over a floor joist, then that floor joist should be doubled.

Article 9.23.9.8 provides these requirements, which are summarized in Figure 14:12.

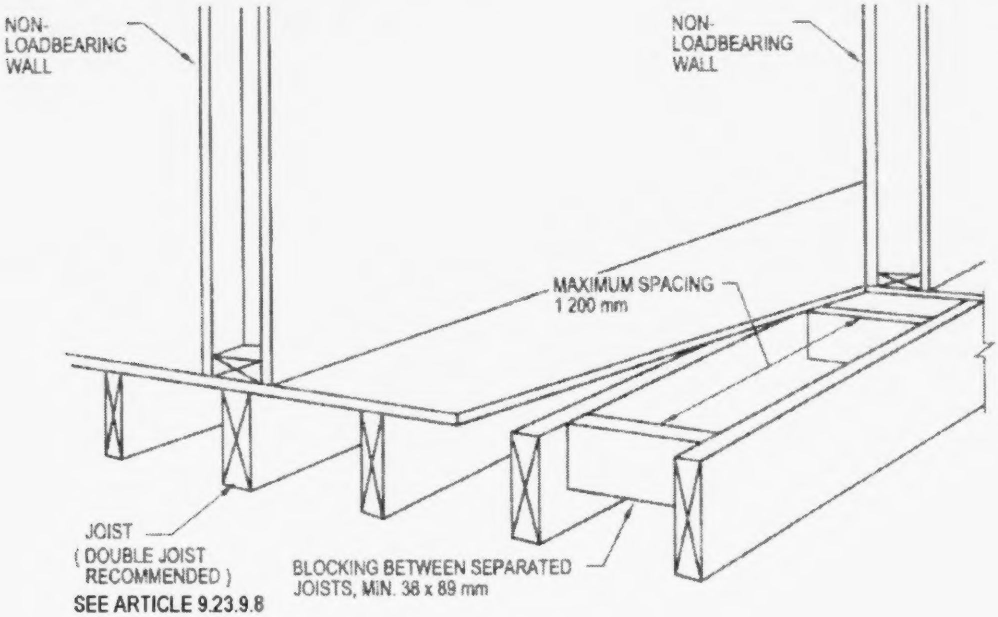

NON-LOADBEARING WALL
NON-LOADBEARING WALL
MAXIMUM SPACING 1 200 mm
JOIST (DOUBLE JOIST RECOMMENDED)
SEE ARTICLE 9.23.9.8
BLOCKING BETWEEN SEPARATED JOISTS, MIN. 38 x 89 mm

Figure 14:12
Non-loadbearing Wall Supported on Floor

Loadbearing walls can also run either perpendicular or parallel to the floor joists. However, *loadbearing* walls running parallel to floor joists must be supported below by another *loadbearing* wall or beam capable of carrying the loads to suitable vertical supports. When *loadbearing* walls are run perpendicular to floor joists, they must be located near the support of the floor joist, as shown in Figure 14:13.

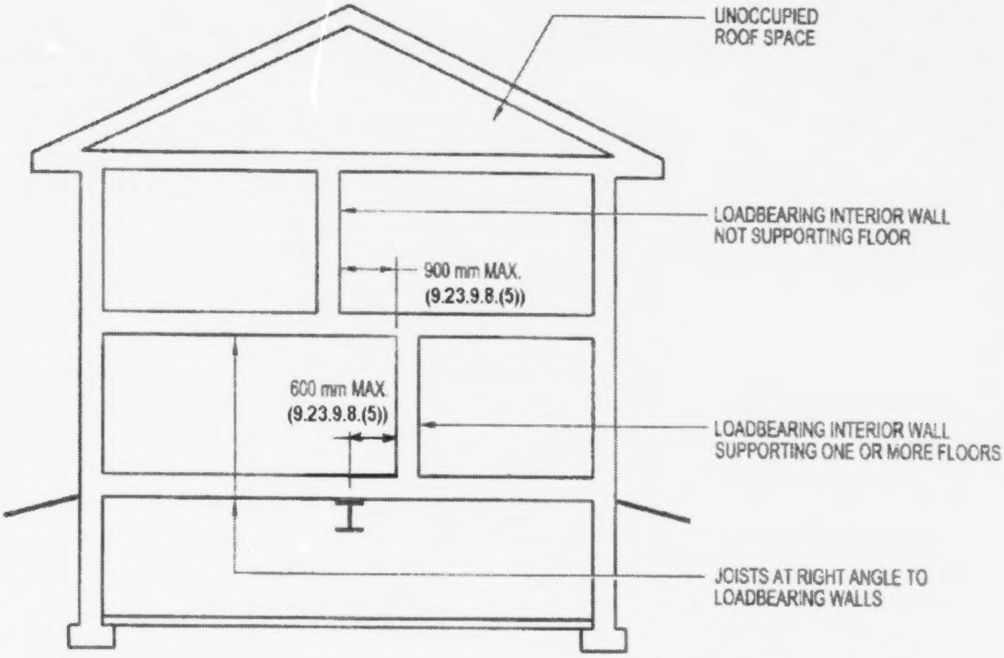

UNOCCUPIED ROOF SPACE
LOADBEARING INTERIOR WALL NOT SUPPORTING FLOOR
900 mm MAX. (9.23.9.8.(5))
600 mm MAX. (9.23.9.8.(5))
LOADBEARING INTERIOR WALL SUPPORTING ONE OR MORE FLOORS
JOISTS AT RIGHT ANGLE TO LOADBEARING WALLS

Figure 14:13

Loadbearing Wall Supported on Floor

Cantilevered floor joists are allowed provided that they do not support loads other than roof loads and do not cantilever more than 400 to 600 mm depending on the joist depth.

If the cantilever supports other loads from floors above, then the design of these joists are to be done in accordance with Part 4.

Figure 14:14 provides a summary of Article 9.23.9.9 on cantilevered floor joists.

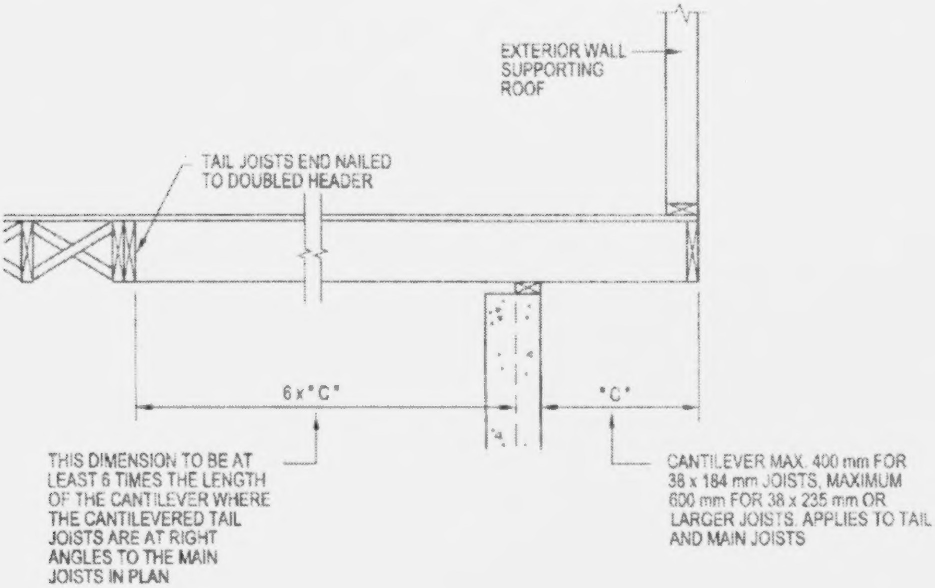

EXTERIOR WALL SUPPORTING ROOF
TAIL JOISTS END NAILED TO DOUBLED HEADER
6 x "C"
"C"
THIS DIMENSION TO BE AT LEAST 6 TIMES THE LENGTH OF THE CANTILEVER WHERE THE CANTILEVERED TAIL JOISTS ARE AT RIGHT ANGLES TO THE MAIN JOISTS IN PLAN
CANTILEVER MAX. 400 mm FOR 38 x 184 mm JOISTS, MAXIMUM 600 mm FOR 38 x 235 mm OR LARGER JOISTS. APPLIES TO TAIL AND MAIN JOISTS

Figure 14:14
Cantilevered Floor Joists

Exercise #14-2

Read Subsection 9.23.8, and Articles 9.23.9.5 to 9.23.9.9. Answer the following questions, then discuss your answers with your group.

1. Consider a situation in which 38 mm x 184 mm grade SPF No. 2 floor joists are used, and where there are no concentrated loads on the floor joists. Based on the requirements of Part 9, what are the maximum allowable spans for the following:

   a) Under a living room, spaced at 300 mm, with strapping, and with no ceiling?

   ____

   b) Under a living room, spaced at 400 mm, with strapping and bridging, and no ceiling?

   ____

   c) Under a bedroom, spaced at 300 mm with gypsum-board fastened to furring on the underside? (without bridging)

   ____

   d) Under a bedroom, spaced at 400 mm with gypsum-board fastened to furring on the underside? (without bridging)

   ____

   OBC Reference(s): ________________

2. Consider a single storey house with a built-up wood beam (4 – 38 mm x 184 mm No. 2 Spruce) supporting the centre of the main floor as shown in Figure 14:15 below. Assuming that the beam is laterally supported, what is the maximum allowable span L?

   a) 3.0 metres

   b) 2.95 metres

   c) 3.14 metres

   d) 3.08 metres

   OBC Reference(s): ______________

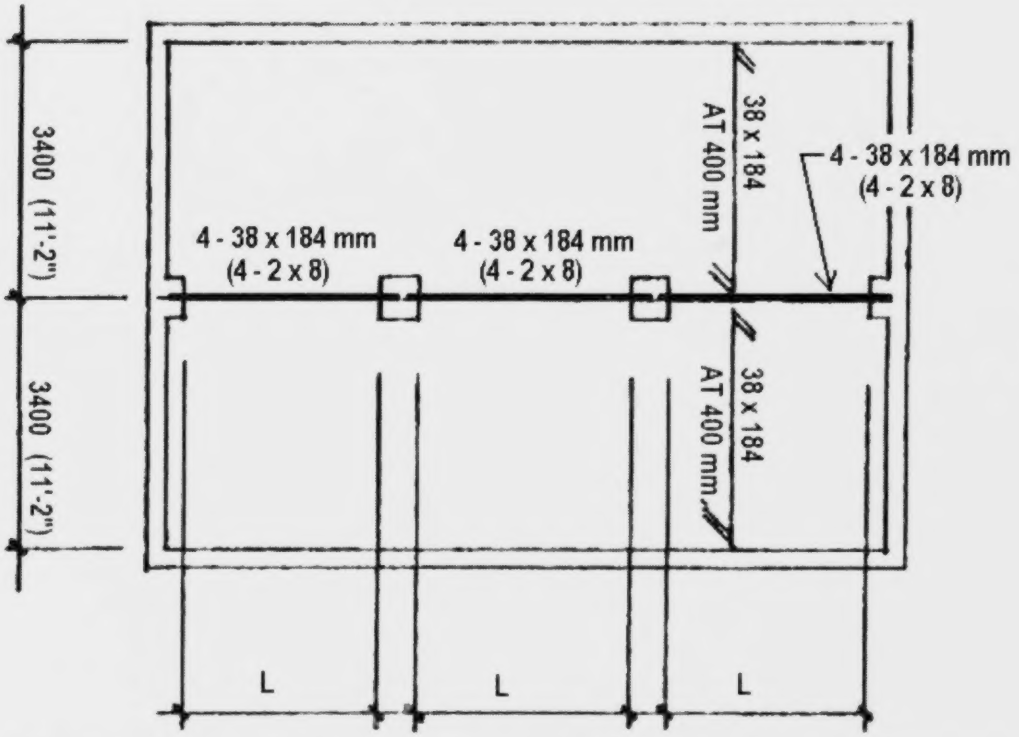

3400 (11'-2")
3400 (11'-2")
4 - 38 x 184 mm
(4 - 2 x 8)
4 - 38 x 184 mm
(4 - 2 x 8)
38 x 184
AT 400 mm
4 - 38 x 184 mm
(4 - 2 x 8)
38 x 184
AT 400 mm
L
L
L

Figure 14:15
Floor Framing for Exercise #14-2

3. If a 130x266 deep glue-laminated beam was substituted in question 2, what would be the maximum allowable span L?

   a) 4.36 metres

   b) 4.10 metres

   c) 3.98 metres

   d) 4.23 metres

   OBC Reference(s): ________________

4. What is the minimum requirement for the floor joist span shown in question 2 to be acceptable? (Assume SPF No. 2 lumber)

   a) Strapping

   b) Bridging

   c) Strapping and bridging

   d) Ceiling attached to wood furring with bridging.

5. At what length does the size of a header joist need to be determined by calculation when greater than:

   a) 800 mm long

   b) 1200 mm long

   c) 2000 mm long

   d) 3200 mm long

   OBC Reference(s): ________________

6. An opening is to be made in a wood-framed floor. The opening is to be 2400 mm perpendicular to the floor joists and 1100 mm wide parallel with the floor joists. What needs to be done to the header and trimmer joists around the opening?

____

____

____

OBC Reference(s): ______________

STOP

14.4 SUBFLOORING

Subflooring, like roof sheathing, creates a diaphragm for the transfer of lateral loads to the vertical supports of the structure, once properly attached. In addition to this lateral load function, the subflooring also transfers vertical loads to the floor joists. The direction of installation and edge support of subflooring follows the same rules as roof sheathing. There are different requirements for selection of panel thickness and these are in Table 9.23.14.5.A and Table 9.23.15.5.B. Subsection 9.23.14 provides the full requirements for subflooring.

Exercise #14-3

Read Subsection 9.23.14. Answer the following questions, then discuss your answers with your group.

1. What condition must exist to allow the use of particleboard as a subflooring material?

   a) The upper surface and all edges must be treated to resist water absorption when used in bathrooms and other areas subject to periodic wetting.

   b) Particleboard shall conform to grade D-2 or D-3 in ANSI A208.1.

   c) Particleboard must have all edges supported by a minimum 38x38 timber blocking.

   d) *Building* must be constructed in a factory so that the subfloor will not be exposed to the weather.

   OBC Reference(s): ________________

STOP

14.5 ENGINEERED FLOOR SYSTEMS

Engineered floor systems consisting of wood I's or wood-truss floor joist systems are required to be designed under Part 4 and the design should be sealed by a Professional Engineer. Similarly, the use of cold-formed steel channels in housing has become increasingly popular in recent years, however such systems also must be designed under Part 4.

When reviewing the plans that include engineered floor systems, the following list of items can serve as a good checklist to make sure that the drawings are complete:

- *Design loads* (*Dead*, *Live*) both uniform and concentrated
- Grade and type of lumber
- Member sizes clearly identified
- Elevation of truss geometry
- Support locations (walls, beams, girders)
- Joist locations
- Joist spacing
- Maximum allowable spans
- Bracing and bridging locations
- Member bearing length and hanger types
- Connection details (typical and special conditions)
- Permitted areas of cutting of members
- Required reinforcement around openings or where members need to be cut
- ______________________________
- ______________________________

STOP End of Module 14

MODULE 15

WALL CONSTRUCTION – PART 9 BUILDINGS

BUILDING STRUCTURAL – 2006

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15.0 Introduction 1
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15.7 Steel Stud Systems 15

15.0 INTRODUCTION

In this Module, we will learn the requirements for wall construction as it relates to the construction of *buildings* that conform to Part 9.

15.1 OBJECTIVES

Upon completion of this Module, participants will be able to:

- Discuss the limitations of the member selection methods of Part 9, and when Part 4 applies
- Review specific words and terminology pertaining to wood-framed construction, and identify important construction components
- Recognize the differences between platform and balloon construction
- Recognize the concept of lateral bracing and unsupported height of walls (i.e. two-*storey* walls)
- Select size and spacing of studs or interior and exterior *loadbearing* and non-*loadbearing* walls
- Select spans for wood lintels
- Apply the requirements for lintels and double studs
- Identify the requirements for wall plates
- Recognize the importance of sheathing in providing lateral stability, and the Code requirements for selection of sheathing
- Recognize the requirements for steel stud systems

15.2 GENERAL DISCUSSION

Wall construction includes the vertical, horizontal and diagonal (bracing) framing members. These members provide the support for floors above and lateral load resistance in the case of *loadbearing* walls, and space delineation in the case of non-*loadbearing* walls. In the case of exterior walls, they also serve as the support for the *building* envelope (thermal, air and moisture protection).

There are two different methods of wall construction in multi-*storey*, wood frame construction. The two methods are platform and balloon construction.

Platform construction will be addressed within this Module, however a brief description of balloon construction will be presented here so that the reader is able to identify this type of construction as it requires some special attention, particularly with respect to the unsupported height of walls.

For two-*storey* houses, in balloon construction the vertical wall supports are continuous between the foundation and roof. In contrast, platform construction involves the construction of the building on a series of platforms, with walls only spanning a single storey each.

Figures 15:1 and 15:2 illustrate balloon and platform framing.

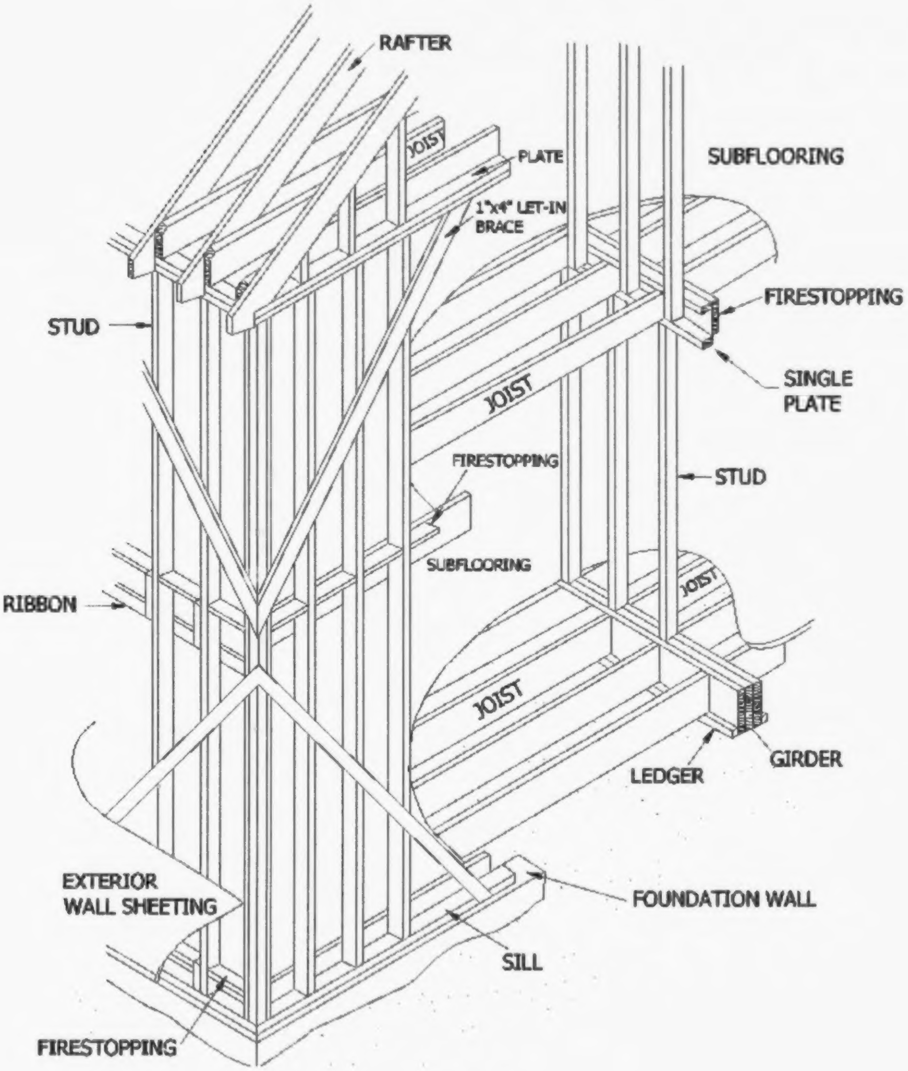
RAFTER
JOIST
PLATE
SUBFLOORING
1"x4" LET-IN BRACE
FIRESTOPPING
STUD
SINGLE PLATE
JOIST
FIRESTOPPING
STUD
SUBFLOORING
RIBBON
JOIST
JOIST
GIRDER
LEDGER
EXTERIOR WALL SHEETING
FOUNDATION WALL
SILL
FIRESTOPPING

Figure 15:1
Balloon Construction

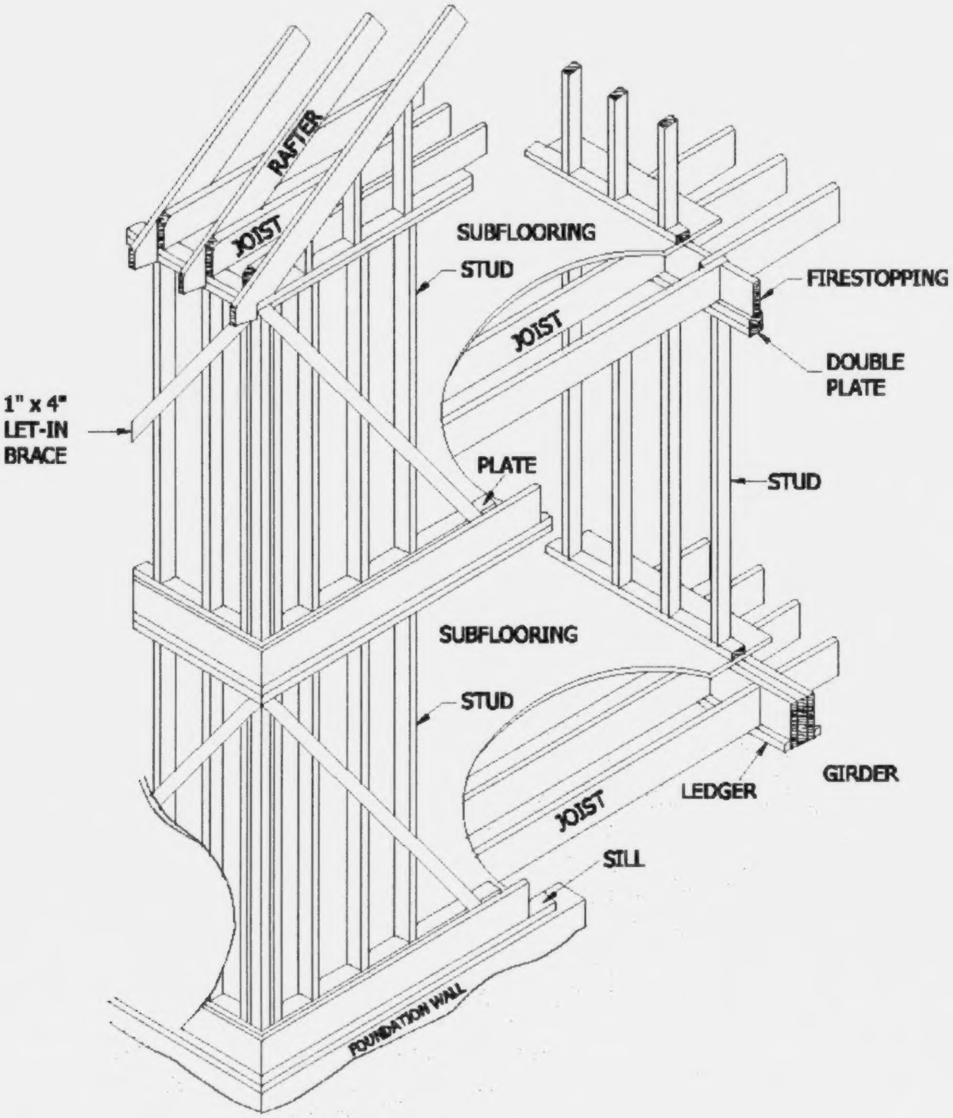
RAFTER
JOIST
SUBFLOORING
STUD
FIRESTOPPING
JOIST
DOUBLE PLATE
1" x 4" LET-IN BRACE
PLATE
STUD
SUBFLOORING
STUD
GIRDER
LEDGER
JOIST
SILL
FOUNDATION WALL

Figure 15:2
Platform Construction

15.3 SIZE AND SPACING OF WOOD STUDS

The requirements for determining the size and spacing for a particular type of wall construction are provided in Article 9.23.10.1. The factors affecting the selection are: the type of wall, the supported loads, the stud spacing, the maximum unsupported height, the wall cladding or bracing, and the orientation of the studs.

Exercise #15-1

Read Articles 9.23.10.1 to 9.23.10.5.
Answer the following questions then discuss the answers with the group.

1. Consider Figure 15:2 with a *storey* height of 2.6 metres. What is the minimum exterior wall stud size and maximum spacing for the wall between the second floor and the roof?
   a) 38 x 38 @ 400 on centre
   b) 38 x 64 @ 600 on centre
   c) 38 x 89 @ 600 on centre
   d) 38 x 140 @ 400 on centre

   OBC Reference(s): ________________

2. Which of the following would be acceptable if the wall in Question 1 was between the top of the foundation wall and the second floor?
   a) 38 x 38 @ 400 on centre
   b) 38 x 64 @ 600 on centre
   c) 38 x 89 @ 400 on centre
   d) 38 x 89 @ 600 on centre

   OBC Reference(s): ________________

3. List the conditions where bracing is not required for a stud wall.

   i) ______________________________________

   ii) ______________________________________

   iii) ______________________________________

   iv) ______________________________________

OBC Reference(s): ________________

STOP

15.4 OPENINGS IN WALLS

Special framing is required around openings in wood framed construction. The requirements for this special framing are provided in Article 9.23.10.6 for vertical studs, and in Subsection 9.23.12 for the horizontal framing.

The vertical studs (at each edge of an opening) that provide bearing for the horizontal member are typically called jack studs or inner studs. The additional vertical stud that extends from top plate to bottom plate is typically called the king stud or outer stud. The horizontal member used to span the opening is typically called a lintel.

Figure 15:3 provides an illustration of the typical members to frame a wall opening. The Figure uses the terms "inner" and "outer" to refer to the jack and king studs, respectively.

Tables A-12 to A-16 may be used to select lintel sizes, subject to certain limitations and provisions. Article 9.23.12.3 and the notes to the lintel tables provide essential guidance on the use of the tables.

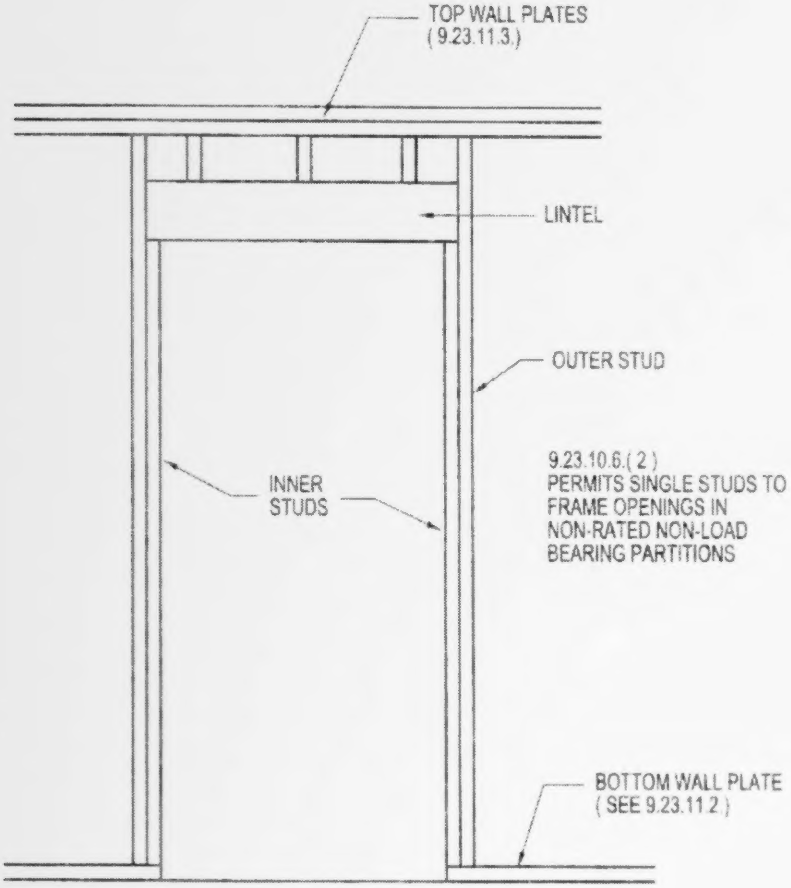
TOP WALL PLATES
(9.23.11.3.)
LINTEL
OUTER STUD
INNER
STUDS
9.23.10.6.(2)
PERMITS SINGLE STUDS TO
FRAME OPENINGS IN
NON-RATED NON-LOAD
BEARING PARTITIONS
BOTTOM WALL PLATE
(SEE 9.23.11.2.)

Figure 15:3
Wall Opening Framing

Exercise #15-2

Read Article 9.23.10.6, Subsection 9.23.12 and Tables A-12 to A-16.
Answer the following questions, then discuss the answers with your group.

1. In Figure 15:4, consider that the studs are spaced at 600 mm centers and that the wall is loadbearing. What is the maximum clear width of the opening such that double studs are not mandatory on each side of the opening?

   a) 400 mm

   b) 600 mm

   c) 1200 mm

   d) 2400 mm

   OBC Reference(s): ____________________

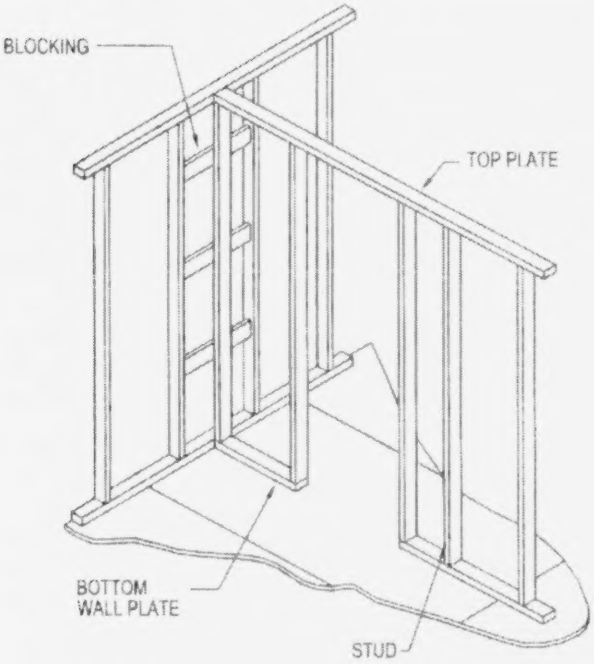

Figure 15:4
Example Framing (Exercise #15-2)

2. In Figure 15:4, what is missing from the diagram if the opening shown is 1100 mm wide and has been made in a *loadbearing* wall?
   (Assume 38 x 89 at 600 spacing stud construction)

   a) Vertical wall studs to be doubled on either side of the opening.

   b) Opening to be framed with a lintel designed to carry the superimposed loads to adjacent studs.

   c) Opening framed with a lintel designed to carry the superimposed loads to adjacent inner and outer studs on each side of the opening.

   d) Nothing is missing; all details comply with the Code.

   OBC Reference(s): ________________

3. A *loadbearing* exterior wall in a house supports a roof, ceiling and 1 *storey* above. The roof and floor span 3.8 metres to the opposite exterior wall. The specified snow load is 1.5 kPa. What is the minimum required size of lintel, using Spruce-Pine-Fir No. 2 grade, that should be used for an opening of 1100 mm?
   (Hint: Use Table A-15 of Part 9, and assume no structural sheathing is used to support the lintel)

   a) 2 – 38 x 89

   b) 2 – 38 x 140

   c) 2 – 38 x 184

   d) 2 – 38 x 235

4. A *loadbearing* wall in a house supports a roof, ceiling and 1 *storey* above. The roof rafters and floor joists have a span of 3.6 metres, and do not clear span between exterior walls.
   The specified snow load is 2.0 kPa.
   For a 2 - 38 x 184 No. 1 Grade Douglas Fir lintel, which of the following statements is true?

   a) If structural sheathing is not used, the maximum allowable lintel span is 1.420 m

   b) If structural sheathing is not used, the maximum allowable lintel span is 1.420 m

   c) If structural sheathing is used, the maximum allowable span is 1.633 m

   d) If structural sheathing is used, the maximum allowable lintel span is 1.796 m

5. A *loadbearing* interior wall in a house supports a roof, ceiling and 2 *storeys* above. The supported roof and floor framing on each side of the wall has a span of 3.4 metres. The specified snow load is 1.5 kPa. For a wall opening width of 2.0 metres, what is an acceptable unsheathed lintel according to Tables A-12 to A-16?

   a) 2 – 38 x 235, No. 1 Spruce-Pine-Fir

   b) 2 – 38 x 235, No. 1 Hem-Fir

   c) 2 – 38 x 235, No. 1 Douglas Fir - Larch

   d) 80 x 380, 20f-E Glulam Timber

STOP

15.5 WALL PLATES

The top and bottom plates of wall construction perform several important functions:

- First, they provide a means of constructing wall segments so that they can be lifted into place and nailed together.
- Secondly, they provide bearing support between successive platforms (i.e., roof joists to top plates, wall studs to bottom plate, etc.). This bearing support requires the wall plates to act in bending, in cases where roof joists do not align within 50 mm of the wall studs below.
- Finally, the top plate acts as a chord member for the floor diaphragm to allow transfer of shear from the diaphragm to the diaphragm of the wall.

The requirements for wall plates for *buildings* conforming to Part 9 are found in Subsection 9.23.11.

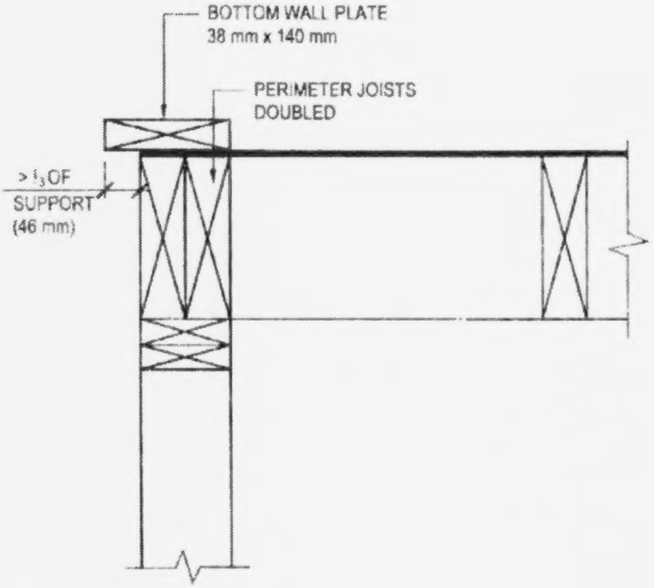

Figure 15:5
Bottom Wall Plate

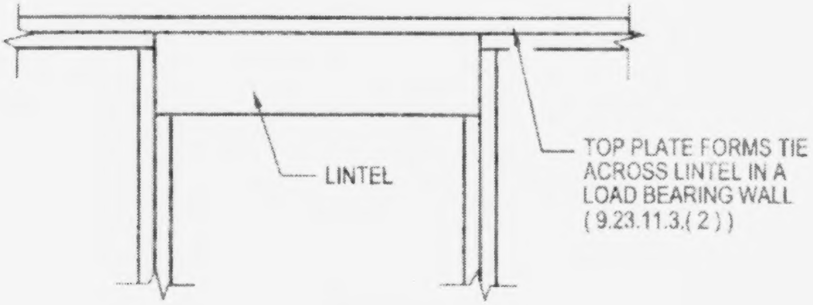
LINTEL
TOP PLATE FORMS TIE ACROSS LINTEL IN A LOAD BEARING WALL (9.23.11.3.(2))

Figure 15:6
Top Wall Plate Over Lintel

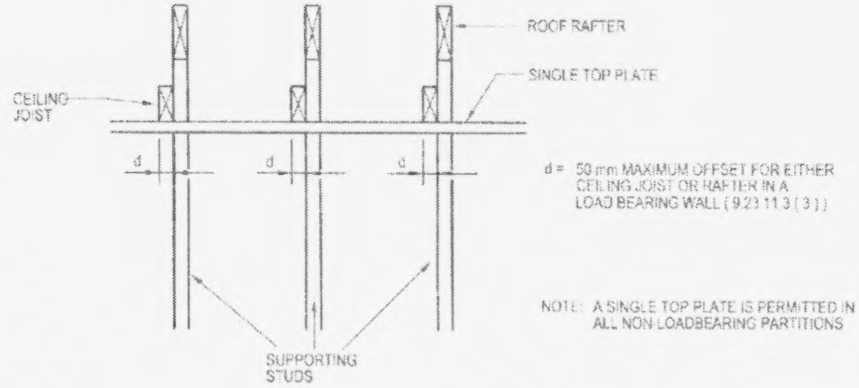
ROOF RAFTER
SINGLE TOP PLATE
CEILING JOIST
d
d
d
d = 50 mm MAXIMUM OFFSET FOR EITHER CEILING JOIST OR RAFTER IN A LOAD BEARING WALL (9.23.11.3 (3))
NOTE: A SINGLE TOP PLATE IS PERMITTED IN ALL NON-LOADBEARING PARTITIONS
SUPPORTING STUDS

Figure 15:7
Single Top Plate, Joist Location

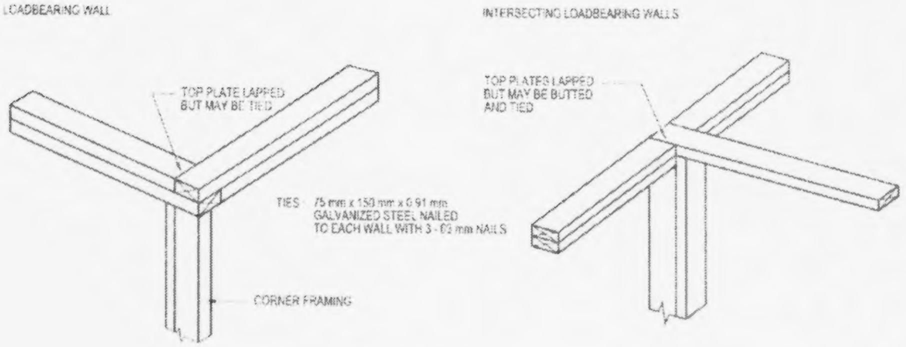
LOADBEARING WALL
INTERSECTING LOADBEARING WALLS
TOP PLATE LAPPED BUT MAY BE TIED
TOP PLATES LAPPED BUT MAY BE BUTTED AND TIED
TIES: 75 mm x 150 mm x 0.91 mm GALVANIZED STEEL NAILED TO EACH WALL WITH 3 - 63 mm NAILS
CORNER FRAMING

Figure 15:8
Top Plate Intersections

Exercise #15-3

Read Subsection 9.23.11 and review Figures 15:5 to 15:8. Answer the following questions, then discuss your answers with your group.

1. Which of the following describe a situation when a single top plate is not acceptable?

   a) Single top plate forms a tie across the top of a lintel.

   b) Single top plate in a non-*loadbearing* wall.

   c) Single top plate where concentrated loads from ceilings, floors and roofs are applied 50 mm beyond one side of the support below.

   d) None of the above

   OBC Reference(s): ________________

2. What is the minimum thickness of a bottom plate in a *loadbearing* wall if the studs are located directly over the framing members below?

   a) 19 mm

   b) 38 mm

   c) 76 mm

   d) No minimum, since the members bear directly on members below.

   OBC Reference(s): ________________

STOP

15.6 WALL SHEATHING

Wall sheathing is required when the exterior cladding system requires intermediate support or solid backing between framing members of the wall, and when no other diagonal bracing system is provided.

The use of wall sheathing as a diagonal bracing system is similar to the roof and floor sheathing concepts studied earlier. The sheathing of the wall creates a diaphragm that resists and transmits lateral loads to the vertical supports and down to the foundation.

Subsection 9.23.16 provides the requirements of wall sheathing for *buildings* that conform to Part 9.

Exercise #15-4

Read Subsections 9.23.16, answer the following question, then discuss your answers with your group.

1. If exterior cladding is to be supported from the wall sheathing which of the following is acceptable sheathing?
   a) Rigid insulation.
   b) Gypsum sheathing.
   c) Insulating fibreboard.
   d) Exterior grade plywood.

   OBC Reference(s): ______________

STOP

15.7 STEEL STUD SYSTEMS

The use of steel stud systems is allowed under Part 9 for all non-*loadbearing* walls. If *loadbearing* walls are to be framed using a steel stud system, then the design of the system is to be done under Part 4. Section 9.24 provides the requirements of steel stud framing systems.

Exercise #15-5

Read Section 9.24, answer the following question, then discuss your answers with your group.

1. What is the minimum steel stud size and maximum spacing for a 3.1 metre high, interior, non-*loadbearing* stud wall?
    a) 30 x 40 spaced at 400 mm.
    b) 30 x 63 spaced at 400 mm.
    c) 30 x 63 spaced at 600 mm.
    d) 30 x 91 spaced at 600 mm.

    OBC Reference(s): ________________

STOP End of Module 15

MODULE 16

ABOVE GROUND MASONRY AND ICF WALLS PART 9 BUILDINGS

BUILDING STRUCTURAL – 2006

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16.0 INTRODUCTION

In this module, we will learn the requirements for above grade masonry and insulating concrete form (ICF) wall construction as it relates to the construction of *buildings* that conform to Part 9.

16.1 OBJECTIVES

Upon completion of this module, participants will be able to:

- Recognize the limitations of the member selection methods of Part 9, and when Part 4 applies
- Explain the concept of lateral support
- Recognize the terminology and differences between the various types of masonry walls, including cavity walls, veneer walls, multi-wythe walls, etc.
- Identify the differences between lintels for wood framing, lintels for non-*loadbearing* veneers, lintels for *loadbearing* masonry, and lintels for ICF walls
- Apply the requirements of Part 9 in the design of masonry and ICF wall elements including connections and wall openings
- Apply the minimum structural requirements for chimneys and fireplaces

16.2 ABOVE GROUND MASONRY AND ICF WALLS LIMITATIONS OF PART 9

Section 9.20 governs the use of above-grade masonry and insulated concrete form (ICF) walls for *buildings* within the scope of Article 9.20.1.1. This Article restricts the use of this Section to unreinforced masonry and masonry veneer that does not extend beyond 11 metres above the *foundation* wall, and that no roof or floor system above the first floor is of concrete construction.

Clause 9.20.1.1.(1)(b) also limits ICF walls to situations where all of the following must be satisfied:

- floor to floor height does not exceed 3 metres
- *building* height is not more than 2 *storeys* and the *building* contains only a single *dwelling unit*
- the location is such that the seismic spectral response acceleration $S_a(0.2)$ is not greater than 0.4.

Walls in a *building* that do not meet the above requirements must be designed using the requirements of Subsection 4.3.2, as stated in sentence 9.20.1.1.(2).

There are two additional elements within Section 9.20 that may require design to be done in conformance of Subsection 4.3.2. These are in Articles 9.20.6.4 and 9.20.6.6. The restrictions deal with the conditions where masonry veneers are supported individually by the back-up material and the use of limestone slab or precast concrete panel facings or veneers.

16.3 MASONRY MATERIALS AND WORKMANSHIP

Masonry materials are relatively simple. They consist of the masonry units (e.g. brick, concrete blocks) and mortar.

The Code requires that masonry units comply with one or more of the standards listed in Article 9.20.2.1. An additional requirement for the masonry units is the compressive strength; the minimum values are specified in Table 9.20.2.7.

The mortar, which is equally if not more important than the units themselves, is governed by Subsection 9.20.3. Mortar consists of a combination of cementitious materials, aggregates, and water. The standards that these components must comply with are listed in Article 9.20.3.1 and the proportions that are to be used are provided in Table 9.20.3.2.B.

Workmanship is very important to the proper construction of a masonry wall. If not built plumb and square, unnecessary stresses can be developed and the wall may only have a fraction of its original design strength. In addition to affecting strength, a poorly built wall can also affect other trades if proper coursing of the masonry units is not carefully monitored. Since the size and shape of the manufactured masonry units is well controlled, the only workmanship-related element of a masonry wall is the arrangement of the joints, or in other words, the relative placement of the units. Subsection 9.20.4 provides the requirements for masonry mortar joints.

Refer to Figure 16:1 for an illustration of the terminology for head and bed joints, as referenced in Subsection 9.20.4.

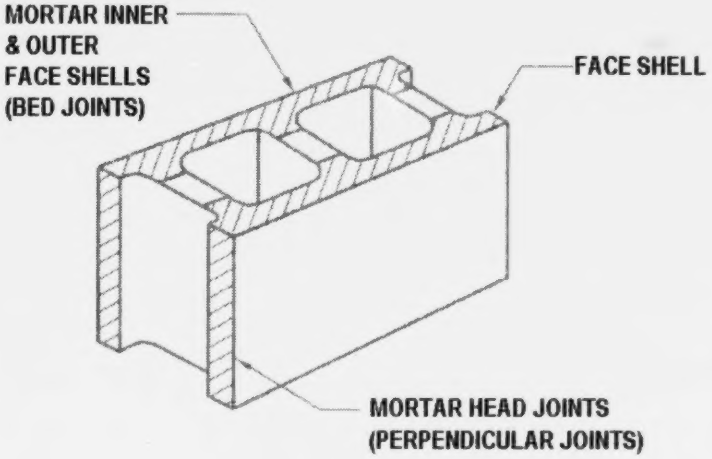

MORTAR INNER
& OUTER
FACE SHELLS
(BED JOINTS)
FACE SHELL
MORTAR HEAD JOINTS
(PERPENDICULAR JOINTS)

Figure 16:1
Mortar Joints

Exercise #16-1

Read Subsections 9.20.2 to 9.20.4 and 9.20.14 and answer the following questions. Then discuss your answers with your group.

1. What minimum compressive strength is required for a solid concrete masonry unit (block) that is to be used for the construction of a *loadbearing* masonry wall exposed to the weather?

   a) 10 MPa

   b) 15 MPa

   c) 5 MPa

   d) Not Permitted

   OBC Reference(s): ________________

2. What is the acceptable range of mortar joint thickness for concrete unit masonry or burned clay brick unit masonry?
   - a) 10 mm, with no allowable variance
   - b) 5 mm to 20 mm
   - c) 10 mm to 15 mm
   - d) 5 mm to 10 mm

OBC Reference(s): ________________

3. Which of the following is an acceptable mortar mix for a *loadbearing* exterior above ground masonry wall?

a) Mortar type N;
Mix proportions 1:1:5
(Portland Cement: Lime: Sand)

b) Mortar type S;
Mix proportions 1:2:8
(Portland Cement: Masonry Cement: Sand)

c) Mortar type S;
Mix proportions 2:1:4
(Portland Cement: Lime: Sand)

d) Mortar type N;
Mix proportions 1:3
(Masonry Cement: Sand)

OBC Reference(s): ________________

4. What is the reference standard for the use of reclaimed brick for a masonry veneer wall in Part 9 construction?
   - a) CAN/CSA-A82.1M
   - b) CAN3-A82.8-M
   - c) CAN/CSA-A165.2-M
   - d) None of the above

OBC Reference(s): ________________

STOP

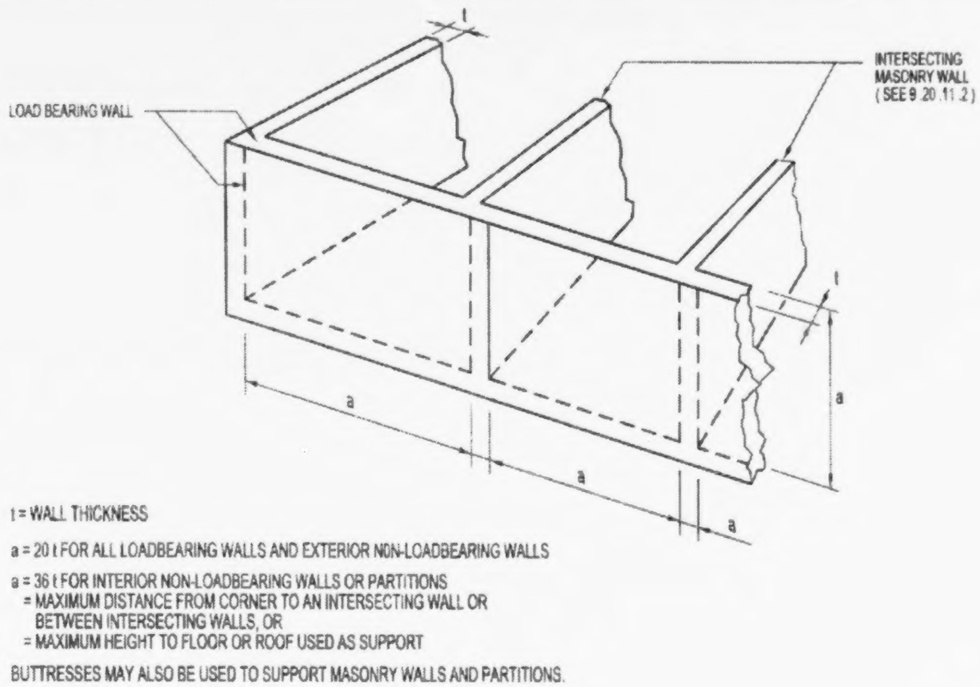
16.4 LATERAL SUPPORT AND WALL HEIGHT RESTRICTIONS

Unreinforced masonry walls are very strong in direct compression. However due to construction tolerances, even the best built wall section is never perfectly plumb and square. In addition to this, the loads applied to a masonry wall are not always centered exactly on the wall cross-section. The result is that walls are required to resist bending moments resulting from these eccentrically applied loads.

Masonry walls resist bending through the balance of their own self-weight and the tension capacity of the bond between the mortar and the masonry unit. Empirical approaches to masonry design have simplified this calculation and relate the strength of masonry to the height/thickness ratio of a wall, in which the height is the "laterally unsupported height." If lateral support to the wall is not provided to achieve the necessary span/thickness ratios, then the wall can become structurally unstable. Many other factors can affect the stability of a masonry wall, but these are beyond the scope of this course.

Subsection 9.20.10 gives the required height to thickness ratios to satisfy the required lateral support for a masonry wall.

Figure 16:2 provides a summary of these requirements. It should be noted in Figure 16:2 that lateral support to masonry walls can be achieved by means of intersecting walls such that the supported wall spans in a horizontal direction.



t = WALL THICKNESS

a = 20 t FOR ALL LOADBEARING WALLS AND EXTERIOR NON-LOADBEARING WALLS

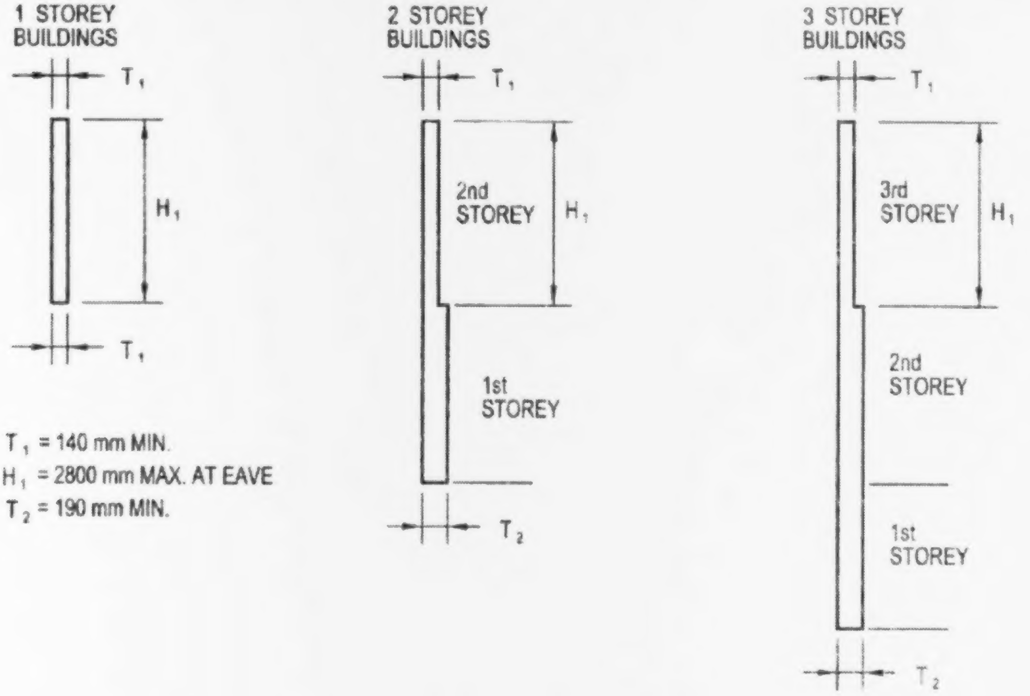
a = 36 t FOR INTERIOR NON-LOADBEARING WALLS OR PARTITIONS
= MAXIMUM DISTANCE FROM CORNER TO AN INTERSECTING WALL OR BETWEEN INTERSECTING WALLS, OR
= MAXIMUM HEIGHT TO FLOOR OR ROOF USED AS SUPPORT

BUTTRESSES MAY ALSO BE USED TO SUPPORT MASONRY WALLS AND PARTITIONS.

Figure 16:2
Masonry Lateral Support

Subsection 9.20.6 provides the requirements for the minimum thicknesses of masonry walls for use in exterior and interior walls, cavity walls, masonry veneer walls and parapet walls. This Subsection also addresses the two conditions when design must be done according to Subsection 4.3.2, as previously identified.

Figure 16:3 provides a summary of the minimum wall thicknesses for exterior masonry walls.


1 STOREY BUILDINGS
2 STOREY BUILDINGS
3 STOREY BUILDINGS
T_1
H_1
2nd STOREY
1st STOREY
3rd STOREY
T_2

T_1 = 140 mm MIN.
H_1 = 2800 mm MAX. AT EAVE
T_2 = 190 mm MIN.

Figure 16:3
Minimum Exterior Wall Thickness

Chases and recesses in masonry walls are acceptable provided certain conditions or restrictions are satisfied. These restrictions are described in Subsection 9.20.7.

Exercise #16-2

Read Subsections 9.20.6, 9.20.7 and 9.20.10. Answer the following questions, then discuss your answers with your group.

1. A 3-*storey* house with *loadbearing* exterior masonry walls is to be constructed from 190 mm concrete masonry units (concrete block) for the lower 2 *storeys* and 140 block for the 3rd *storey*. What is the maximum height of the peak of the gable end allowed?
    a) 2800 mm
    b) 3800 mm
    c) 4600 mm
    d) Unlimited height, provided additional lateral supports are provided at a maximum of 20 times the wall thickness.

OBC Reference(s): ________________

2. If an exterior concrete block wall continues 500 mm above the roofline, what is the minimum wall thickness for this parapet?
    a) 140 mm
    b) 167 mm
    c) 190 mm
    d) 240 mm

OBC Reference(s): ________________

3. For the cavity wall shown in Figure 16:4 (below), what is the equivalent thickness to be used in the determination of the spacing of required lateral supports, if $t_1 = 90$ mm and $W = 50$ mm?

   a) 90 mm

   b) 210 mm

   c) 180 mm

   d) 230 mm

OBC Reference(s): ______________

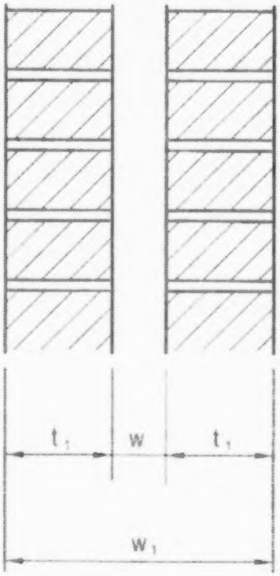


Figure 16:4
Cavity Wall Thickness (Exercise #16-2)

4. For the plan view of the wall shown in Figure 16:5 below, indicate the required minimum spacing and maximum sizes of the recesses shown (assume w = 190 mm)

A = ____________

B = ____________

C = ____________

D = ____________

OBC Reference(s): ______________

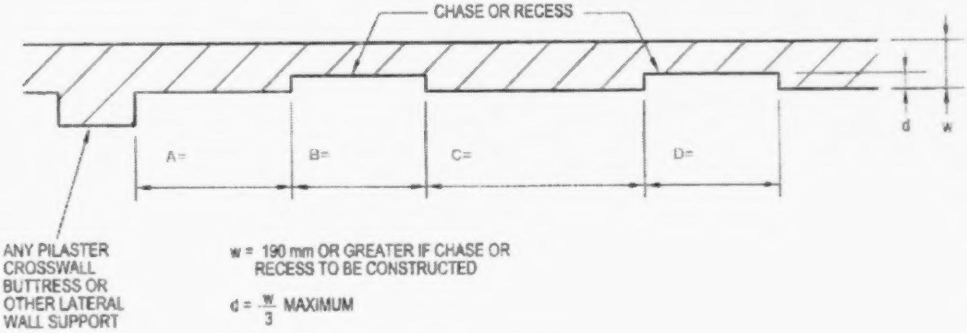

CHASE OR RECESS
d
w
A=
B=
C=
D=
ANY PILASTER
CROSSWALL
BUTTRESS OR
OTHER LATERAL
WALL SUPPORT
w = 190 mm OR GREATER IF CHASE OR
RECESS TO BE CONSTRUCTED
d = w/3 MAXIMUM

Figure 16:5
Chase or Recess Locations (Exercise #16-2)

STOP

16.5 SUPPORT, ANCHORAGE, BONDING AND TYING OF MASONRY

In this section, we will cover the requirements where masonry is required to support loads from other load carrying members, the requirements for proper anchorage to lateral supporting members, and the requirements for bonding or tying together multi-wythe walls.

16.5.1 Support of Loads

Subsection 9.20.8 states the applicable Code requirements where masonry is required to support loads from other load carrying members. The main requirement of a masonry wall at the location of support for load carrying member is that the masonry wall be solid. This can be accomplished either by providing a solid masonry block or by filling the cells of a hollow unit with grout. It is also acceptable in some situations to provide a wood bearing plate of at least 38 mm thick in lieu of solid or grouted masonry. Figure 16:6 below provides an example of this for hollow masonry walls.

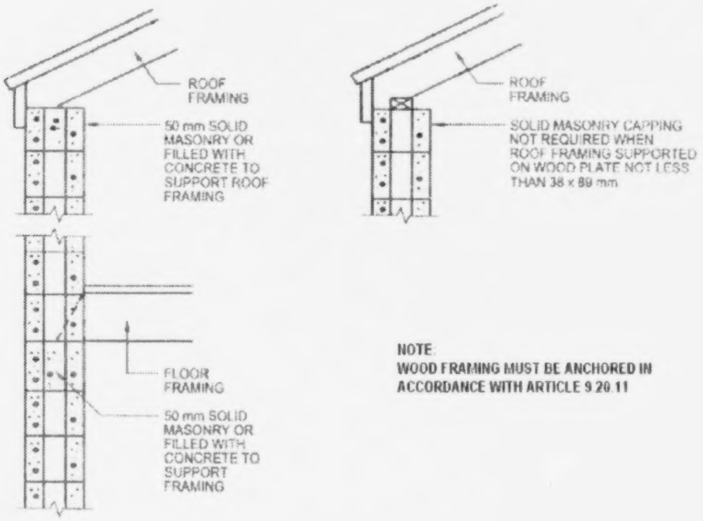

ROOF FRAMING
50 mm SOLID MASONRY OR FILLED WITH CONCRETE TO SUPPORT ROOF FRAMING
ROOF FRAMING
SOLID MASONRY CAPPING NOT REQUIRED WHEN ROOF FRAMING SUPPORTED ON WOOD PLATE NOT LESS THAN 38 x 89 mm
FLOOR FRAMING
50 mm SOLID MASONRY OR FILLED WITH CONCRETE TO SUPPORT FRAMING
NOTE:
WOOD FRAMING MUST BE ANCHORED IN ACCORDANCE WITH ARTICLE 9.20.11

Figure 16:6
Support on Hollow Masonry Walls

16.5.2 Anchorage

At locations where lateral support is to be provided to a masonry wall, it is necessary to properly anchor this lateral support to the masonry wall and to the member providing the support. Subsection 9.20.11 of the Code provides the requirements of this anchorage. Figure 16:7 provides a summary of the anchorage requirements for floor or roof assemblies that are meant to provide lateral support.

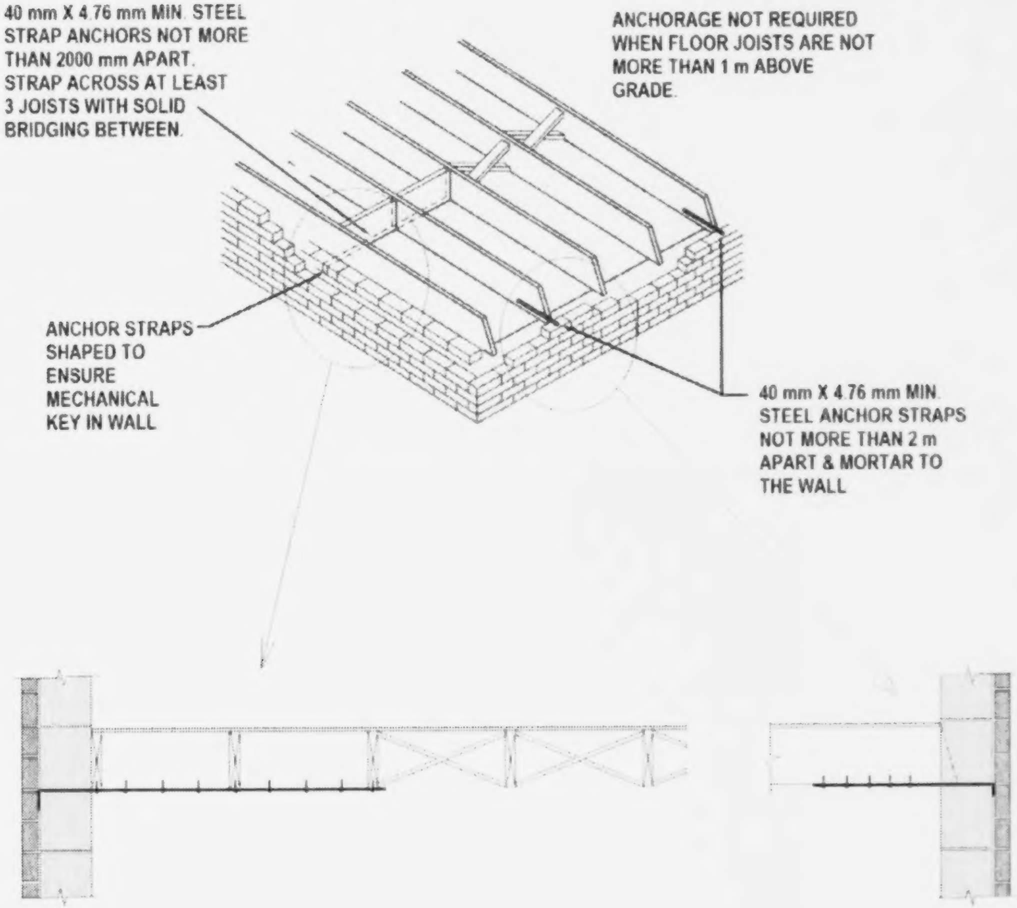

40 mm X 4.76 mm MIN. STEEL STRAP ANCHORS NOT MORE THAN 2000 mm APART. STRAP ACROSS AT LEAST 3 JOISTS WITH SOLID BRIDGING BETWEEN.
ANCHORAGE NOT REQUIRED WHEN FLOOR JOISTS ARE NOT MORE THAN 1 m ABOVE GRADE.
ANCHOR STRAPS SHAPED TO ENSURE MECHANICAL KEY IN WALL
40 mm X 4.76 mm MIN. STEEL ANCHOR STRAPS NOT MORE THAN 2 m APART & MORTAR TO THE WALL

Figure 16:7
Anchorage of Floor or Roof Assemblies (Article 9.20.11.11)

16.5.3 Bonding and Tying

Where intersecting walls are to provide lateral support for masonry walls there is also minimum anchorage requirements to satisfy Article 9.20.11.2, which requires, when intersecting masonry walls are to provide lateral support, that 50% of the adjacent masonry units be bonded together. This bond can be done either by toothing the units together or by mechanical ties spaced not more than 800 mm on centre vertically. The ties are required to be corrosion resistant, shaped to provide a mechanical keying action, and a minimum thickness of 4.76 mm x 40 mm wide.

Article 9.20.11.3 gives the requirements for a wood-framed wall that provides lateral support to a masonry wall. Figure 16:8 provides a summary of those requirements.

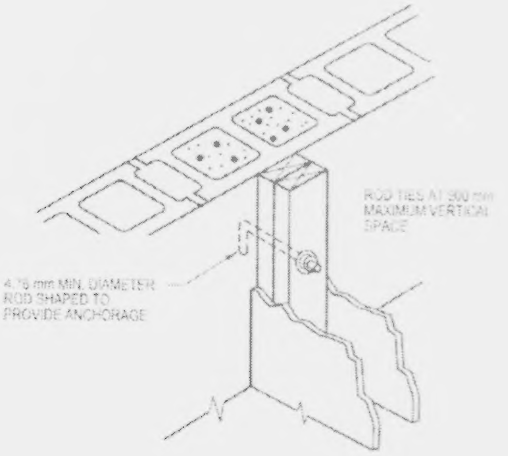


Figure 16:8
Wood Frame Wall – Lateral Support

Article 9.20.11.4 describes the requirements for anchoring wood frame roof construction; this anchorage resists wind uplift of the roof, as well as ensures adequate lateral support to the supporting walls. These requirements are in addition to the lateral support ties mentioned in Article 9.20.11.1 and support requirements of 9.20.8 above. Refer to Figure 16:9.

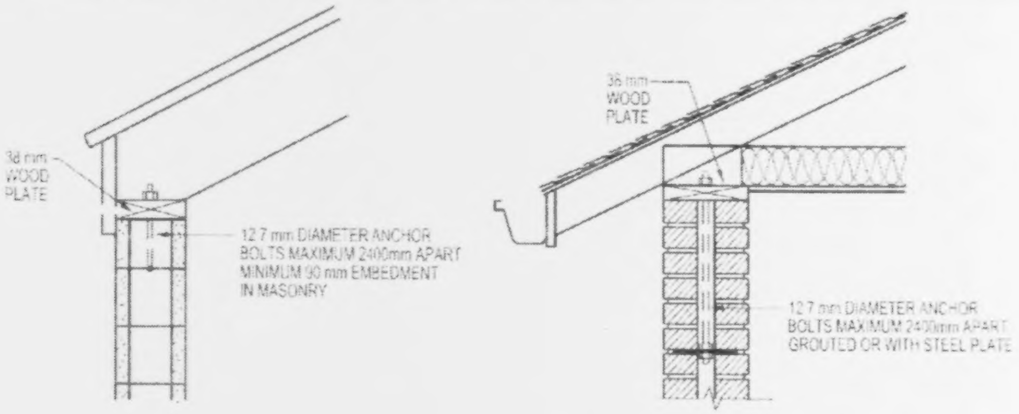

38 mm
WOOD
PLATE
12.7 mm DIAMETER ANCHOR
BOLTS MAXIMUM 2400mm APART
MINIMUM 90 mm EMBEDMENT
IN MASONRY
38 mm
WOOD
PLATE
12.7 mm DIAMETER ANCHOR
BOLTS MAXIMUM 2400mm APART
GROUTED OR WITH STEEL PLATE

Figure 16:9
Wood Frame Roof Anchorage

Bonding and/or tying together multiple wythes of masonry is required to conform to Subsection 9.20.9.

Bonding is the term used when masonry units are set perpendicular to the run of the wall connecting the inner and outer wythes of masonry. Article 9.20.9.3 provides the requirements for this type of connection.

Tying is the term used when individual metal rods are used to connect two wythes of masonry together. The requirements for this type of connection are provided in Article 9.20.9.4. Figure 16:10 provides an example of a metal rod tie.

The tie requirements for masonry veneer are somewhat different to those described above. Masonry veneer, not intended to be *loadbearing* other than its own self-weight, requires ties to provide lateral support to the veneer for stability. The ties are embedded into the veneer and connected to the backup, supporting wall. The complete requirements for masonry veneer ties are provided in Article 9.20.9.5.

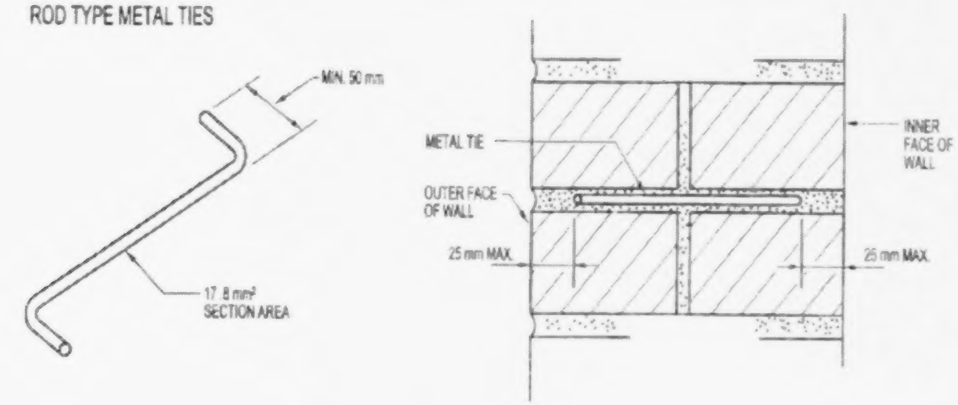

ROD TYPE METAL TIES
MIN. 50 mm
17.8 mm²
SECTION AREA
METAL TIE
OUTER FACE OF WALL
25 mm MAX.
INNER FACE OF WALL
25 mm MAX.

Figure 16:10
Multi -Wythe Tying

Exercise #16-3

Read Subsections 9.20.8, 9.20.9, and 9.20.11.
Answer the following questions, then discuss your answers with your group.

1. What two methods are acceptable for providing support of roof and ceiling members on a cavity wall?
   - ____________________
   - ____________________

   OBC Reference(s): ____________

2. When a masonry wall is made from 2 separate wythes of brick tied together, what is the maximum horizontal and vertical spacing of these ties?
   a) 600 (H) x 500 (V)
   b) 800 (H) x 400 (V)
   c) 900 (H) x 400 (V)
   d) 900 (H) x 460 (V)

   OBC Reference(s): ____________

3. Which of the following is not a requirement for masonry veneer ties?
   a) Spacing as provided in Table 9.20.9.5,
   b) Stainless steel,
   c) Not less than 22 mm. wide
   d) Shaped to provide a key with the mortar.

OBC Reference(s): ________________

STOP

16.6 LINTELS AND ARCHES

The masonry arch is well known for its strength in spanning openings. However, when it is not possible to form an arch due to geometry of the opening or available wall space, a lintel is required to support the masonry. Subsection 9.20.5 provides the requirements for support of masonry. Different requirements exist for *loadbearing* and non-*loadbearing* walls, as well as for masonry veneers.

In addition to these requirements, Article 9.20.12.3 imposes further requirements summarized in Figure 16:11 below.

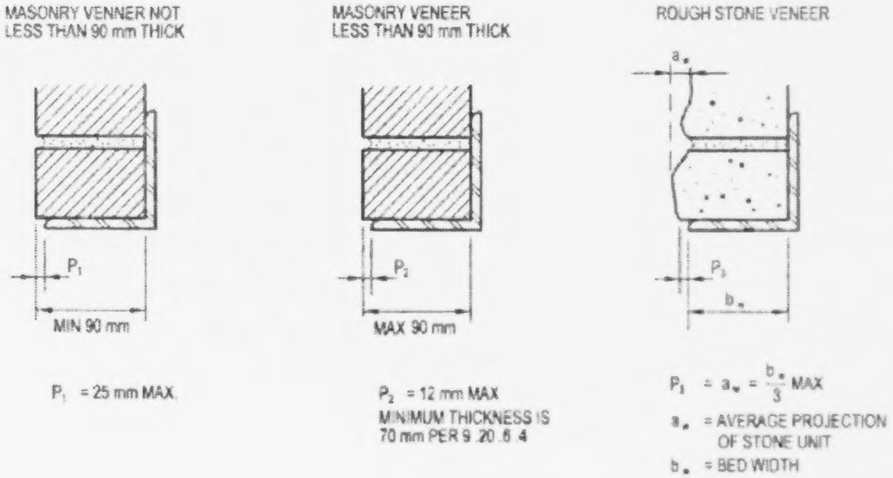

MASONRY VENNER NOT LESS THAN 90 mm THICK
MASONRY VENEER LESS THAN 90 mm THICK
ROUGH STONE VENEER
a_w
P_1
MIN 90 mm
P_2
MAX 90 mm
P_3
b_w
P_1 = 25 mm MAX
P_2 = 12 mm MAX
MINIMUM THICKNESS IS 70 mm PER 9.20.6.4
$P_3 \doteq a_w = \frac{b_w}{3}$ MAX
a_w = AVERAGE PROJECTION OF STONE UNIT
b_w = BED WIDTH

Figure 16:11
Masonry Projection and Lintels

Exercise #16-4

Read Subsection 9.20.5 and answer the following questions.

1. A 1600 mm wide opening is to be provided in a 305 mm single wythe masonry *loadbearing* wall. The wall supports a floor and a roof. The load per metre over the opening has been determined to be 10 kN/m. What is the minimum size of loose steel lintel that should be installed?

   a) L125x90x8

   b) L150x100x10

   c) 2-L125x90x8

   d) 2-L150x100x10

   OBC Reference(s): ________________

2. What is the maximum span of an L90x90x6 steel angle that supports a 90 mm thick brick veneer?

   a) 1200 mm or less

   b) 2300 mm

   c) 2470 mm

   d) 2590 mm

   OBC Reference(s): ________________

Continue to the next **STOP** sign

16.7 CORBELLING

Corbelling is the act of progressively increasing the width of a masonry wall to accommodate changes in wall thickness. Subsection 9.20.12 of the Code provides the requirements for corbelling.

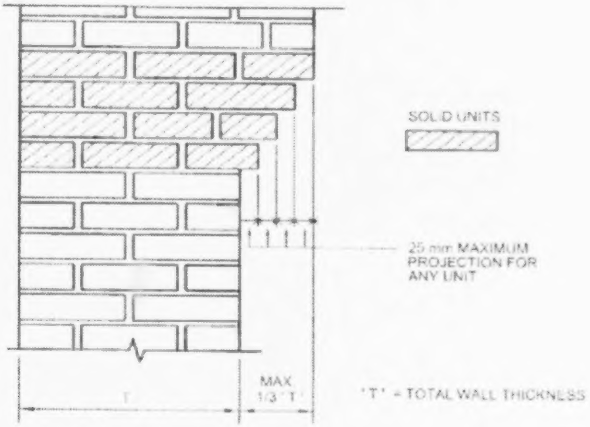

SOLID UNITS
25 mm MAXIMUM PROJECTION FOR ANY UNIT
T
MAX 1/3 'T'
'T' = TOTAL WALL THICKNESS

Figure 16:12
Corbelling

Exercise #16-5

Read Subsection 9.20.12 and answer the following question. Then, discuss the answers to Exercises #16-4 and #16-5 with the group.

1. What is the maximum horizontal projection of a 75 mm thick brick veneer and for a 90 mm thick brick veneer?

   - ____
   - ____

   OBC Reference(s): _______________

STOP

16.8 MASONRY REINFORCEMENT FOR EARTHQUAKES

The requirement for reinforcing in masonry for earthquake loads is provided in Article 9.20.1.2 of the Code. The minimum amount of reinforcing for earthquakes is 0.002 times the horizontal cross-sectional area of the wall. Article 9.20.15.1 also states that a minimum of 1/3 of this reinforcing must be installed horizontally or vertically, with the remaining 2/3 in the other direction.

Exercise #16-6

Read Article 9.20.1.2 and Subsection 9.20.15 and answer the following questions. Then discuss your answers with your group.

1. What is the minimum amount of reinforcing steel required per metre in a 190 mm *loadbearing* masonry block wall for a 2-storey Part 9 building located where the spectral response acceleration Sa(0.2) = 0.4?

   a) 127 mm^2/m

   b) 254 mm^2/m

   c) 380 mm^2/m

   d) None

   OBC Reference(s): ________________

2. What is the minimum amount of reinforcing steel required per metre in a 240 mm *loadbearing* masonry block wall for a 2-storey Part 9 building located in Pembroke Ontario?

   a) 240 mm^2/m Horizontal and Vertical

   b) 400 mm^2/m Horizontal and Vertical

   c) 480 mm^2/m Horizontal

   d) 480 mm^2/m Vertical

   OBC Reference(s): ________________

STOP

16.9 ABOVE GROUND – FLAT INSULATING CONCRETE WALLS

The minimum wall thickness for an above ground ICF wall is 140 mm as provided in Article 9.20.17.1. Minimum wall reinforcing requirements are provided in Article 9.20.17.2 and 9.20.17.3, with reinforcing for openings over 900 mm wide in Article 9.20.17.4.

The requirements for supporting floor joists and roof framing are found in Article 9.20.17.5 and 9.20.17.6.

Exercise #16-7

Read Article 9.20.17.2 and Subsection 9.20.17 and answer the following questions, then discuss your answers with your group.

1. Which of the following is not a requirement for an above ground ICF wall?

   a) Horizontal reinforcement shall not be less than 10M@600 c/c.

   b) Horizontal and vertical reinforcement shall be placed in the middle third of the wall thickness.

   c) Wall thickness must remain constant over the entire height of the wall.

   d) Two additional 10M vertical reinforcing bars are to be placed on either side of openings that interrupt vertical reinforcing bars.

   OBC Reference(s): ________________

2. A 1500 mm opening is to be provided in a 190 mm thick *loadbearing* ICF wall supporting a second storey and a light framed roof. Which of the following meets the minimum reinforcing requirements (ground snow load 1.5 kN/m^2)?

   a) 300 mm Deep lintel reinforced with 1-10M bottom bar and 10M stirrups at 150 mm spacing.

   b) 300 mm Deep lintel reinforced with 1-15M bottom bar and 10M stirrups at 300 mm spacing.

   c) 300 mm Deep lintel reinforced with 2-15M bottom bars.

   d) 500 mm Deep lintel reinforced with 1-10M bottom bar and 10M stirrups at 250 mm spacing.

   OBC Reference(s): ________________

STOP

16.10 MOISTURE PROTECTION

While not technically a structural concern, moisture protection does protect the structural integrity of a building. The use of flashing, weep holes, and sheathing paper help protect the *building* structure from moisture. In previous modules, we have covered the requirements for sheathing paper. Subsection 9.20.13 provides the requirements for flashing and weep holes in masonry and Article 9.20.17.7 provides the requirements for ICF walls. Figures 16:13 and 16:14 provide examples of the flashing and weep hole requirements for masonry.

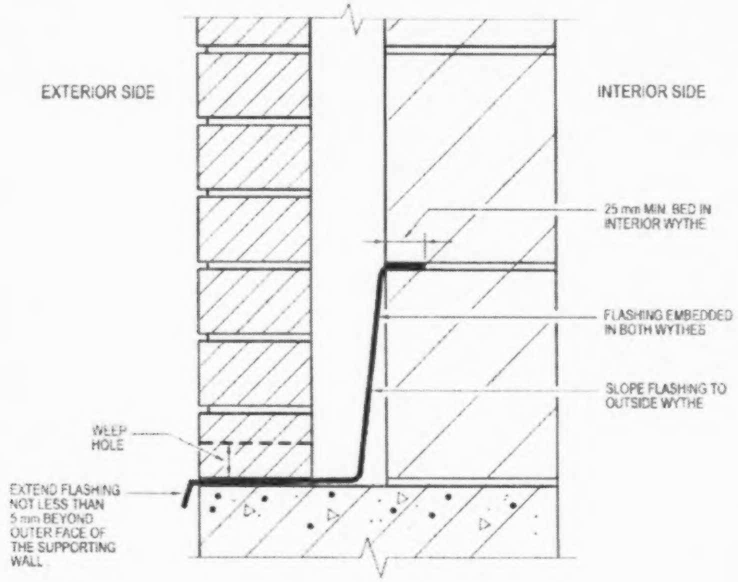

EXTERIOR SIDE
INTERIOR SIDE
25 mm MIN. BED IN INTERIOR WYTHE
FLASHING EMBEDDED IN BOTH WYTHES
SLOPE FLASHING TO OUTSIDE WYTHE
WEEP HOLE
EXTEND FLASHING NOT LESS THAN 5 mm BEYOND OUTER FACE OF THE SUPPORTING WALL

Figure 16:13
Flashing Cavity Wall

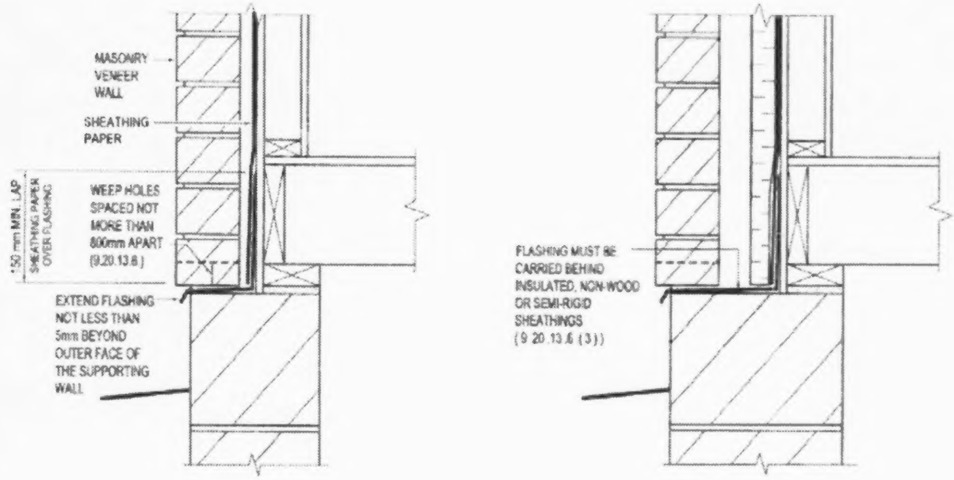

MASONRY VENEER WALL
SHEATHING PAPER
150 mm MIN. LAP SHEATHING PAPER OVER FLASHING
WEEP HOLES SPACED NOT MORE THAN 800mm APART (9.20.13.8.)
EXTEND FLASHING NOT LESS THAN 5mm BEYOND OUTER FACE OF THE SUPPORTING WALL
FLASHING MUST BE CARRIED BEHIND INSULATED, NON-WOOD OR SEMI-RIGID SHEATHINGS (9.20.13.6.(3))

Figure 16:14
Flashing Masonry Veneer

16.11 CHIMNEYS AND FIREPLACES

While Sections 9.21 and 9.22 deal with the requirements of *chimneys* and fireplaces in this module, we are only interested in two Articles, 9.21.4.5 on lateral stability of *chimneys* and 9.22.5.2 on support of fireplace hearths.

Exercise #16-8

Read Articles 9.21.4.5 and 9.22.5.2 and answer the following questions, then discuss your answers with your group.

1. What two conditions must be met for a *chimney* not to require lateral bracing?

   - ____
     ____
   - ____
     ____

   OBC Reference(s): ________________

2. What is the minimum thickness of a reinforced concrete slab that is to support the fire chamber floor and hearth of a fireplace? Can this slab be designed under Part 9?

   Minimum thickness = ________________

   Part 9? ☐ Yes ☐ No

   Why? ________________________________

   OBC Reference(s): ________________

STOP End of Module 16

MODULE 17

OTHER STRUCTURAL COMPONENTS PART 9 BUILDINGS

TABLE OF CONTENTS

17.0 Introduction 1
17.1 Objectives 1
17.2 Columns 2
17.3 Handrails 6
17.4 Guards 7
17.5 Cantilevered Precast Concrete Steps 14
17.6 Notching and Drilling of Wood Framing 16

17.0 INTRODUCTION

In this Module, we will learn the requirements for some other structural components not explicitly covered in the previous Modules, as they relate to the design and construction of *buildings* that conform to Part 9.

17.1 OBJECTIVES

Upon completion of this Module, participants will be able to:

- Determine the allowable limits for notching and drilling of wood framing selected under Part 9,
- Recognize the differences between Part 4 and Part 9 design requirements for columns, *guards* and handrails,
- Select column sizes using prescriptive requirements of Part 9,
- Apply the requirements and limitations of prefabricated adjustable steel columns,
- Apply the requirements for anchorage of structures,
- Select handrails and *guards* using Part 9 and Supplementary Standards.

17.2 COLUMNS

The design requirements for columns under Part 9 are covered in Section 9.17. This Section only applies for columns used to support carport roofs and beams carrying loads from:

- not more than two wood-framed floors
- tributary width not greater than 5 metres
- floor design *live load* not greater than 2.4 kPa, and
- beams or header joists supporting exterior platforms subject to the limitations in Clause 9.17.1.1.(1)(b).

If the column is used for any other purpose, or the loading requirements are exceeded then the design must be completed in accordance with Part 4 of the Code.

Subsections 9.17.3 and 9.17.4 provide the requirements for steel and wood columns respectively. Masonry and concrete columns are addressed by Subsections 9.17.5 and 9.17.6 respectively.

Subsection 9.35.4 provides additional requirements regarding column sizes and anchorage requirements for garage and carport columns.

Exercise #17-1

Read Section 9.17, Subsections 9.23.6 and 9.35.4. Answer the following questions, then discuss the answers with your group.

1. For which of the following conditions would the use of an adjustable steel column be acceptable?

   a) A column supporting a live load of 2.4 kPa over a supported area of 10 square metres.

   b) A column meeting the requirements of CAN/CGSB-7.2 supporting a load of 3 kPa from a single interior wood frame floor with a supported area of 10 square metres.

   c) A column meeting the requirements of CAN/CGSB-7.2 supporting a beam from a single level exterior platform where the supported length of the joists is 4 metres, the supported beam length is 3 metres and the combined specified snow load and occupancy load is 4.8 kPa.

   d) A column that conforms to CAN/CGSB-72 supporting a load of 36 kN from a car port roof.

   OBC Reference(s): ________________

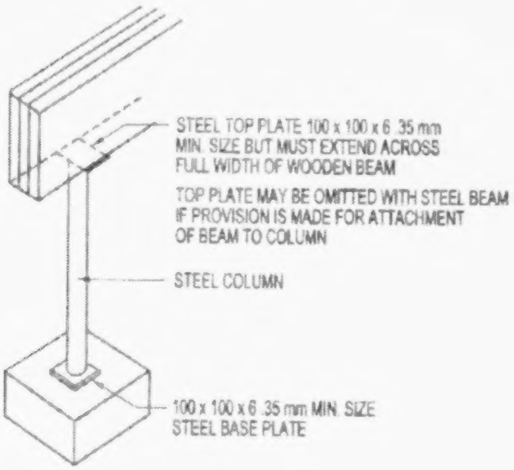

STEEL TOP PLATE 100 x 100 x 6.35 mm
MIN. SIZE BUT MUST EXTEND ACROSS
FULL WIDTH OF WOODEN BEAM
TOP PLATE MAY BE OMITTED WITH STEEL BEAM
IF PROVISION IS MADE FOR ATTACHMENT
OF BEAM TO COLUMN
STEEL COLUMN
100 x 100 x 6.35 mm MIN. SIZE
STEEL BASE PLATE

Figure 17:1
Steel Column

2. Unless designed in accordance with Part 4, what is the minimum allowable column size and thickness for the steel column shown in Figure 17:1 above?
   a) HSS 73 x 3.8
   b) HSS 73 x 6.4
   c) DN73 STD Pipe (5.16 mm Wall Thickness)
   d) HSS 73 x 4.76

   OBC Reference(s): ______________

3. Which of the following would not be an acceptable column size according to Section 9.17? (Assume all other requirements are met.)
   a) 140 mm x 140 mm Wood Column
   b) 230 mm Diameter Concrete Column
   c) 240 mm x 240 mm Solid Masonry Column
   d) 240 mm x 380 mm Masonry Column

OBC Reference(s): ______________

b)

4. What are the two acceptable methods for fabricating the built up wood columns shown in Figure 17:2?

- ____
- ____

OBC Reference(s): ____________________

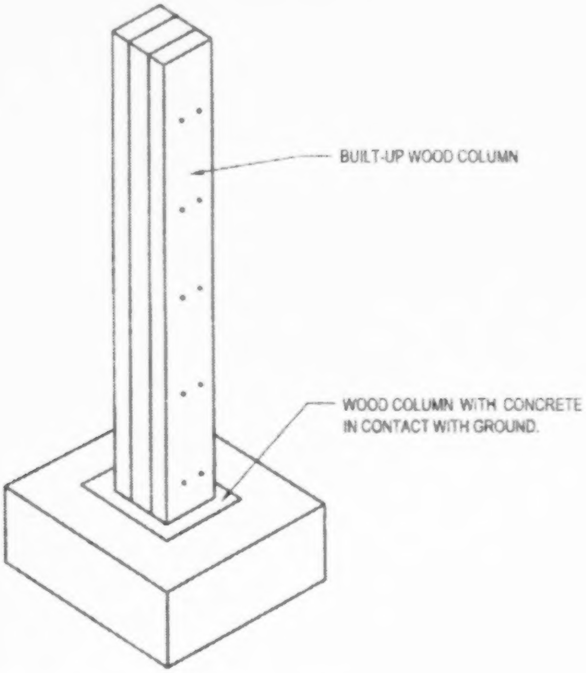

BUILT-UP WOOD COLUMN
WOOD COLUMN WITH CONCRETE IN CONTACT WITH GROUND.

Figure 17:2
Built-Up Wood Column

5. What is required at the base of the interior wood column shown in Figure 17:2?

a) 100 x 100 x 6.35 mm steel base plate

b) Anchorage to resist uplift and lateral movement

c) 0.05 mm polyethylene sheet

d) None of the above

OBC Reference(s): ____________________

STOP

17.3 HANDRAILS

As previously covered in Module 8, a handrail is a horizontal or sloping rail intended for grasping by the hand for guidance or support.

In this Module, the discussion of handrails is limited to their attachment, in Part 9 *buildings*. Article 9.8.7.7 provides the minimum attachment requirements. Handrails are to be attached to suitable supporting elements with not less than 2 wood screws at each point penetrating not less than 32 mm into solid wood. (i.e. wood studs, blocking, steel studs, masonry, etc.). The distance between attachment points is not to exceed 1200 mm with the first attachment point being within 300 mm of each end of the handrail.

17.4 GUARDS

Guards are a protective barrier around openings in floors or at the open sides of stairs, landings, balconies or other locations to prevent accidental falls form one level to another.

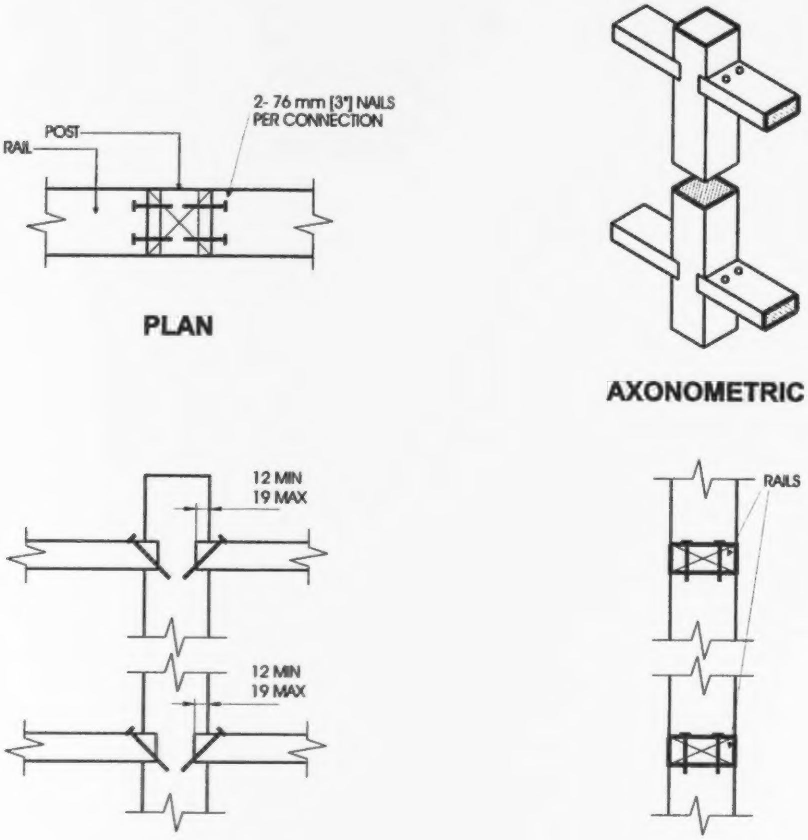
Article 9.7.5.3 provides requirements where windows are used to act as a guard over siairs, ramps and landings. Article 9.7.5.4 provides similar requirements for windows above the second storey in public areas of buildings of residential occupancy. The structural design of the glass must conform to CAN/CGSB-12.20-M as directed in Article 9.7.3.2. These windows are required to either be protected by guards that conform to the requirements of Subsection 9.8.8 or the window must be designed to withstand the lateral loads for guards as provided in Articles 4.1.5.15 or 9.8.8.2.

Subsection 9.8.8 provides the requirements for *guards*. This Module is only concerned with the construction of the *guard*. Article 9.8.8.2 requires that *guards* must resist the loading in Table 9.8.8.2. It also states that *guards* constructed in conformance with the requirements in Supplementary Standard SB-7 shall be deemed to satisfy this requirement. Subject to the limitation of Sentence 9.8.8.2.(4), *guards* proven to provide effective performance may be exempt from the requirements of Table 9.8.8.2.

Supplementary Standard SB-7 has prescriptive requirements for exterior *guards* and interior *guards*.

The construction of exterior *guards* is subdivided into 2 subsections: Materials and Structural Details. The materials for exterior *guards* shall be a minimum graded lumber meeting requirements of Northern Species No. 2 with pickets allowed to be Northern Species No. 2 picket grade. Table 2.1.2 of the Supplementary Standard SB-7 provides the minimum sizes for various *loadbearing* elements for exterior *guards*. The structural details are divided into two systems: post and rail, and cantilevered picket. Table 2.2.1 and Table 2.2.2 of the Supplementary Standard SB-7 provides a key to selecting prescriptive details for the different components of each system.

The following three figures provide examples of acceptable exterior *guard* attachments for Part 9 *buildings*, as shown in the Supplementary Standard SB-7.


2- 76 mm [3"] NAILS
PER CONNECTION
POST
RAIL
12 MIN
19 MAX
12 MIN
19 MAX
RAILS

PLAN

AXONOMETRIC

FRONT ELEVATION

SIDE ELEVATION

Figure 17:3
Attachment Top/Bottom Rail To Post
(Refer to Detail EA-2 in SB-7 for additional notes and limitations not reproduced here)

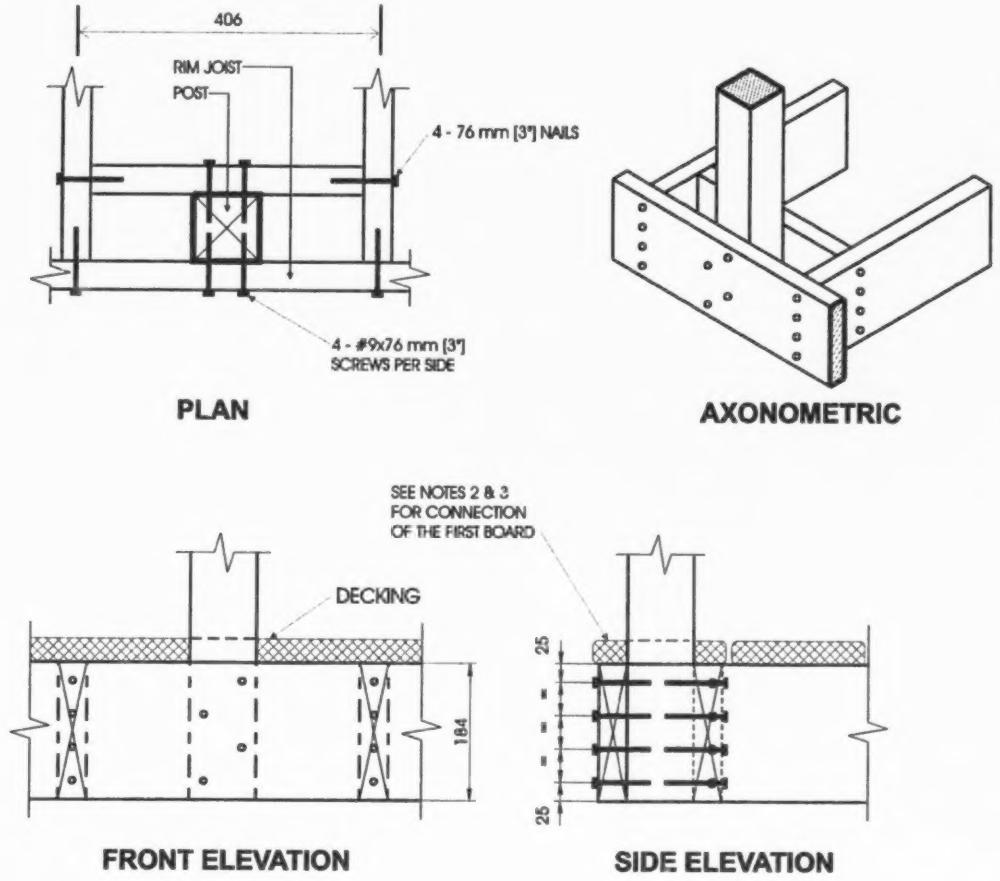
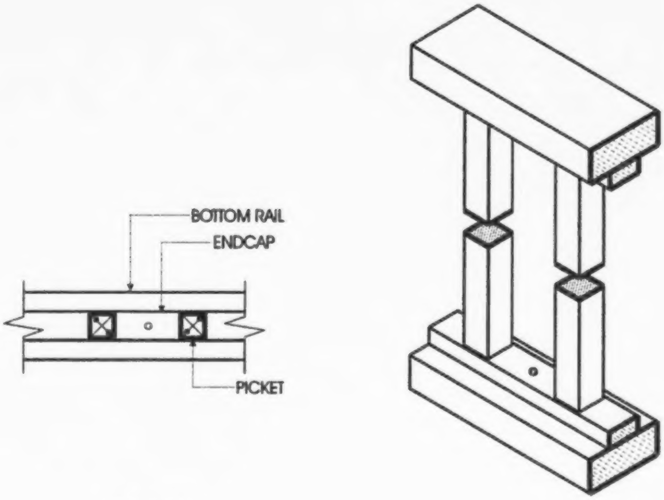

406
RIM JOIST
POST
4 - 76 mm [3"] NAILS
4 - #9x76 mm [3"]
SCREWS PER SIDE
PLAN
AXONOMETRIC
SEE NOTES 2 & 3
FOR CONNECTION
OF THE FIRST BOARD
DECKING
184
25
25
FRONT ELEVATION
SIDE ELEVATION

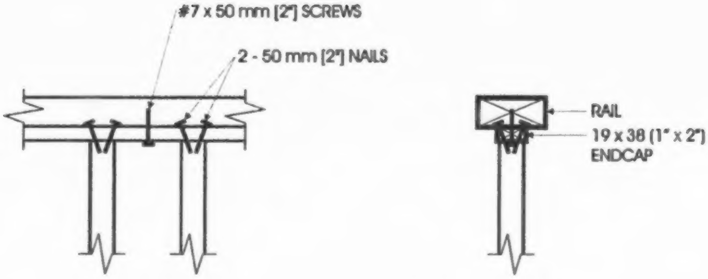
Figure 17:4
Attachment Post to Joist
(Post Screwed to Rim Joist)

(Refer to Detail EB-1 in SB-7 for additional notes and limitations not reproduced here)


BOTTOM RAIL
ENDCAP
PICKET

PLAN
BOTTOM RAIL

AXONOMETRIC


#7 x 50 mm [2"] SCREWS
2 - 50 mm [2"] NAILS
RAIL
19 x 38 (1" x 2")
ENDCAP

FRONT ELEVATION

SIDE ELEVATION

Figure 17:5
Attachment of Baluster (Pickets)

(Refer to Detail EC-1 in SB-7 for additional notes and limitations not reproduced here)

The construction of interior *guards* is broken down in a similar fashion as that of the exterior *guards*. Table 3.1.2 of the Supplementary Standard SB-7 provides the minimum requirements for loadbearing elements for interior *guards*. The structural details are divided into two systems: post-and-rail and cantilevered picket. Tables 3.2.1 to 3.2.3 of the Supplementary Standard SB-7 provide a key to selecting conforming details for the component of each system.

The following two figures provide examples of acceptable interior *guard* attachments for Part 9 *buildings*, as shown in the Supplementary Standard .

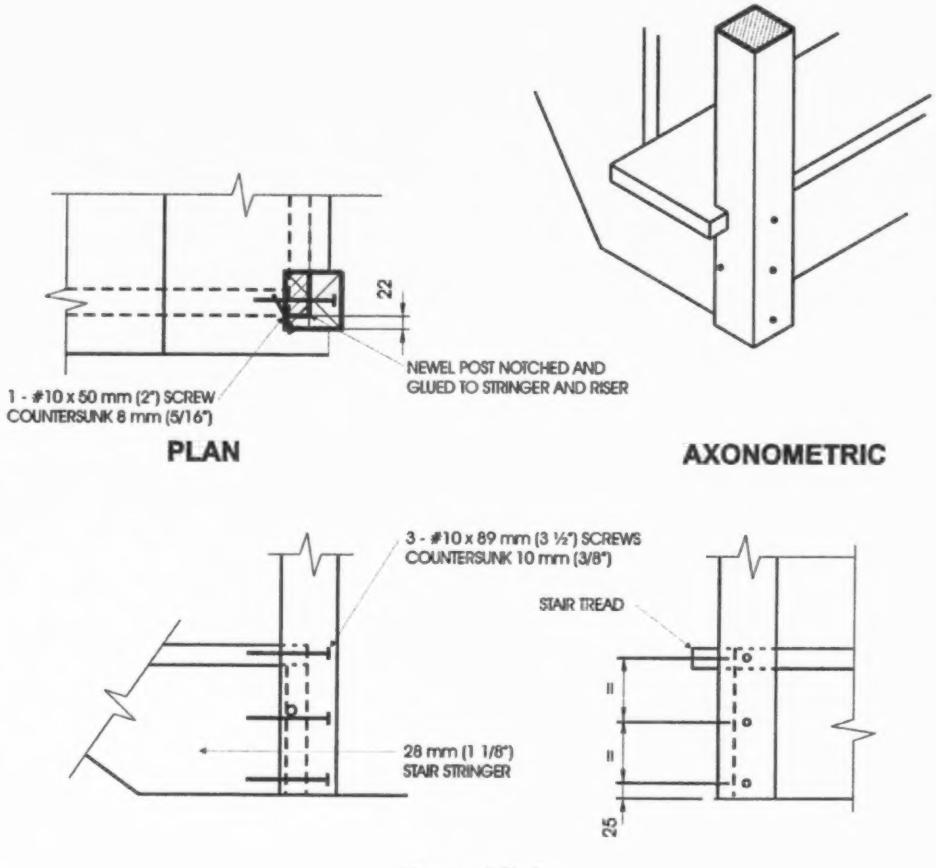

22
NEWEL POST NOTCHED AND GLUED TO STRINGER AND RISER
1 - #10 x 50 mm (2") SCREW COUNTERSUNK 8 mm (5/16")
PLAN
AXONOMETRIC
3 - #10 x 89 mm (3 ½") SCREWS COUNTERSUNK 10 mm (3/8")
STAIR TREAD
28 mm (1 1/8") STAIR STRINGER
25

Figure 17:6
Connection - Bottom Newel Post

(Refer to Detail IG-1 in SB-7 for additional notes and limitations not reproduced here)

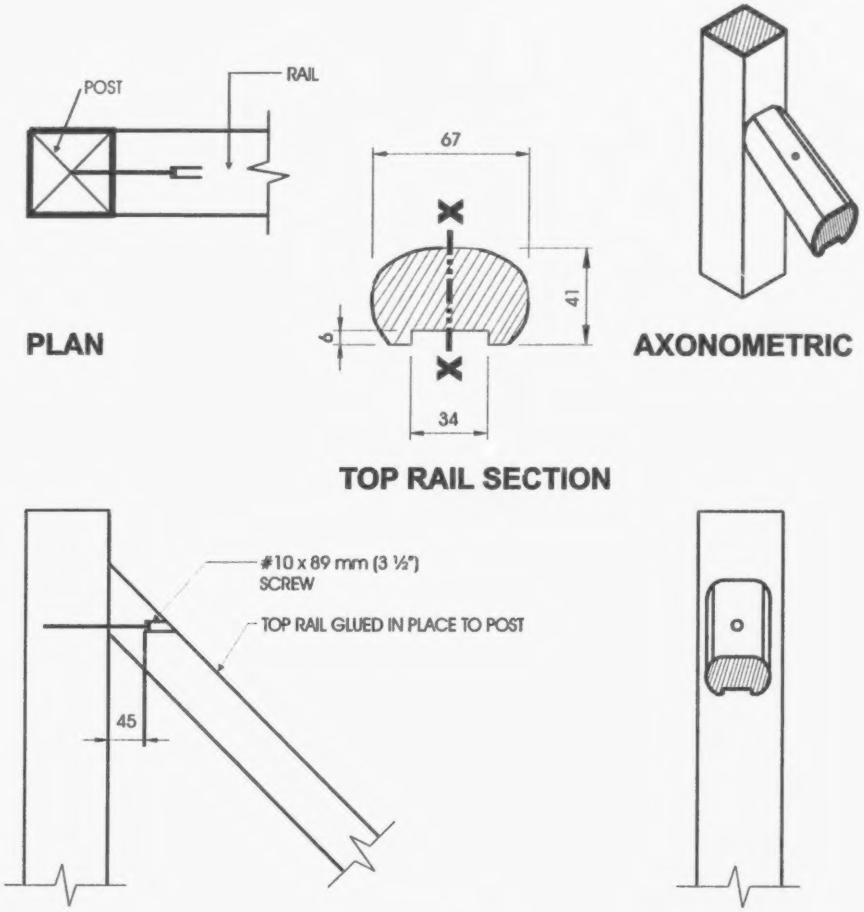

POST
RAIL
PLAN
67
41
6
34
TOP RAIL SECTION
AXONOMETRIC
#10 x 89 mm (3 ½")
SCREW
TOP RAIL GLUED IN PLACE TO POST
45

Figure 17:7
Connection -Top Stringer to Header

(Refer to Detail IF-1 in SB-7 for additional notes and limitations not reproduced here)

Exercise #17-2

Read Article 9.8.7, Article 9.8.8 and Supplementary Standard SB-7. Answer the following questions.

1. A steel *guard* for a stair landing at a townhouse (Part 9) is required. What is the minimum size of support post to be used?

____

____

OBC Reference(s): __________________

d)

2. A handrail is to be installed in a single dwelling unit. Which of the following statements is false?

   a) If the handrail is connected to brick veneer, the connections shall be designed to support a 0.9 kN (minimum) concentrated load

   b) If the handrail is connected to brick veneer, the connections shall be designed to support the greater of a
   0.9 kN concentrated load or a uniformly distributed load of 0.7 kN/m

   c) If the handrail is connected to wood studs, the connections shall have a maximum spacing of 1.2 m

   c) If the handrail is connected to wood studs, each connection shall have a minimum of two wood screws with a penetration of 32 mm into solid wood

   OBC Reference(s): __________________

3. To which detail in SB-7 would an exterior *guard*, constructed as a Post and Rail System with the posts bolted to floor joist with 8 mm bolts, be required to conform?
   a) EB-2
   b) EB-3
   c) EB-4
   d) EB-5

   OBC Reference(s): ______________

STOP

17.5 CANTILEVERED PRECAST CONCRETE STEPS

The requirements for the use of cantilevered precast concrete steps are provided in Subsection 9.8.10. The design of the actual steps and anchorage is not found in Part 9 and so has to be designed to Part 4.

Figure 17:8 provides an example of a possible system.

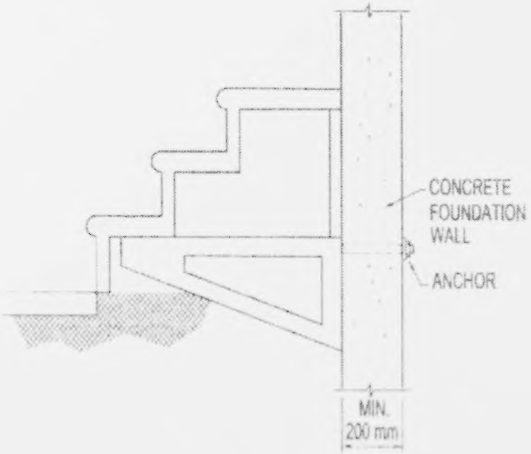


Figure 17:8
Cantilevered Precast Concrete Step Attachment

The Code not only restricts the installation to a minimum 200 mm concrete *foundation* wall, but also requires that suitable attention is given to the backfilling and grading so that a load reversal due to frost heave does not damage the system or *foundation* wall.

Exercise #17-3

Read Subsection 9.8.10 and Article 9.8.9.1, and answer the following question. Then discuss the answer with your group.

1. What is the loading for the design of precast concrete stairs cantilevered from a foundation wall of a single-family dwelling?

   a) 1.9 kPa

   b) 2.4 kPa

   c) 3.6 kPa

   d) 4.8 kPa

   OBC Reference(s): ______________

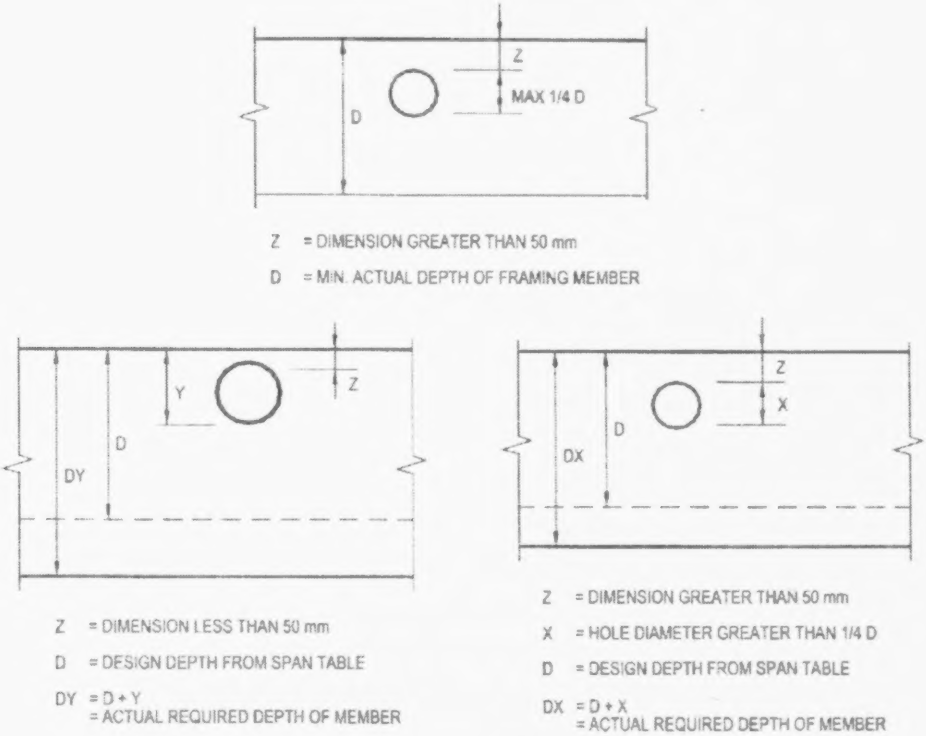
STOP

17.6 NOTCHING AND DRILLING OF WOOD FRAMING

The ease of which wood framing can be cut to suit an application also makes it easily subject to unacceptable modification. Workers involved in the installation of *building* services such as plumbing and electrical generally do their work after the framing is complete, and may not be aware of the structural requirements for drilling and notching of wood framing. It is important that wood framing be examined prior to its concealment by finishes, to ensure that any notching and drilling complies with the Code

Notching and drilling holes in wood framing reduces the strength of the member. Subsection 9.23.5 provides the limitations to which a wood member may be notched and drilled.

Roof truss members are not to be drilled or notched unless these allowances have been specifically accounted for in their design.


Z
MAX 1/4 D
D
Y
Z
D
DY
Z
X
D
DX

Z = DIMENSION GREATER THAN 50 mm

D = MIN. ACTUAL DEPTH OF FRAMING MEMBER

Z = DIMENSION LESS THAN 50 mm

D = DESIGN DEPTH FROM SPAN TABLE

DY = D + Y
= ACTUAL REQUIRED DEPTH OF MEMBER

Z = DIMENSION GREATER THAN 50 mm

X = HOLE DIAMETER GREATER THAN 1/4 D

D = DESIGN DEPTH FROM SPAN TABLE

DX = D + X
= ACTUAL REQUIRED DEPTH OF MEMBER

Figure 17:9
Holes in Floor or Ceiling Joists

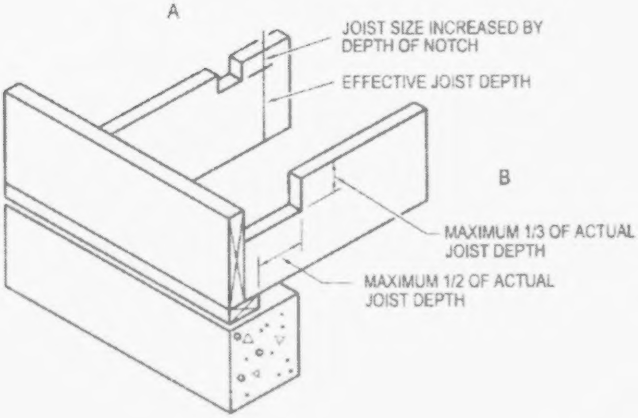

A
JOIST SIZE INCREASED BY DEPTH OF NOTCH
EFFECTIVE JOIST DEPTH
B
MAXIMUM 1/3 OF ACTUAL JOIST DEPTH
MAXIMUM 1/2 OF ACTUAL JOIST DEPTH

Figure 17:10
Notches in Floor or Ceiling Joists

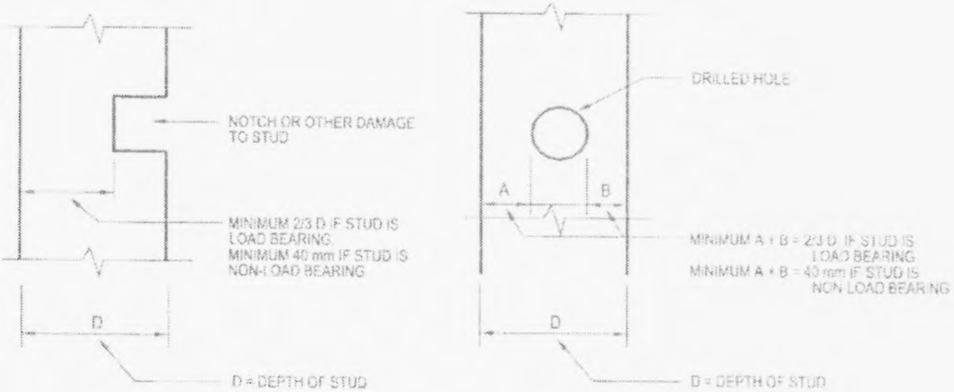

NOTCH OR OTHER DAMAGE TO STUD
MINIMUM 2/3 D IF STUD IS LOAD BEARING
MINIMUM 40 mm IF STUD IS NON-LOAD BEARING
D
D = DEPTH OF STUD
DRILLED HOLE
A
B
MINIMUM A + B = 2/3 D IF STUD IS LOAD BEARING
MINIMUM A + B = 40 mm IF STUD IS NON LOAD BEARING
D
D = DEPTH OF STUD

Figure 17:11
Notches and Holes in Wall Studs

Exercise #17-4

Read Subsection 9.23.5 and answer the following questions. Then discuss your answers with your group.

1. A notch is required in a floor joist near the support. The floor joist is 38 mm x 184 mm S-P-F No.1 at 400 mm on centre and spans 3.55 metres, with bridging. What is the maximum depth of notch allowed?
   - a) 0 mm (joist is at its span limit)
   - b) 61 mm
   - c) 70 mm
   - d) 184 mm

OBC Reference(s): ____________

2. If the joist member in question 2 above were a 38 x 235 mm joist. What would be the maximum notch allowed?

   a) 70 mm

   b) 78 mm

   c) 112 mm

   d) 118 mm

   OBC Reference(s): ________________

3. What is the maximum hole diameter that can be made in 38 mm x 235 mm floor joists spaced at 400 mm on centre, with bridging. The span is 3.5 metres. (Lumber S-P-F No.1)? (Use Table A-1)

   a) 46 mm

   b) 51 mm

   c) 58 mm

   d) 97 mm

   OBC Reference(s): ________________

4. What is the maximum diameter of a hole permitted in a 38 x 140 mm loadbearing wall stud when there is no additional reinforcing of the wall stud present?

   a) 40 mm

   b) 46 mm

   c) 93 mm

   d) 100 mm

   OBC Reference(s): ________________

STOP End of Module 17

MODULE 18

SPECIAL BUILDING TYPES

BUILDING STRUCTURAL – 2006

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18.0 Introduction 1
18.1 Objectives 1
18.2 Log Construction 1
18.3 Park Model Trailers 3
18.4 Cottages 5

18.0 INTRODUCTION

In this Module, we will look at the structural issues related to special *building* types such as log construction and park model trailers that are covered in Part 9 of the Building Code.

18.1 OBJECTIVES

Upon completion of this Module participants will be able to:

- Recognize the special provisions of Part 9 for Log Construction and Park Model Trailers
- Explain the importance of anchorage of Park Model trailers

18.2 LOG CONSTRUCTION

The use of logs is permitted by the Code provided it can be verified that they are structurally adequate for their intended purposes. Such verification may be done by:

- Structural analysis,
- Testing, or
- Previous experiences.

The requirements of Section 9.37 are additional to those of Section 9.23.

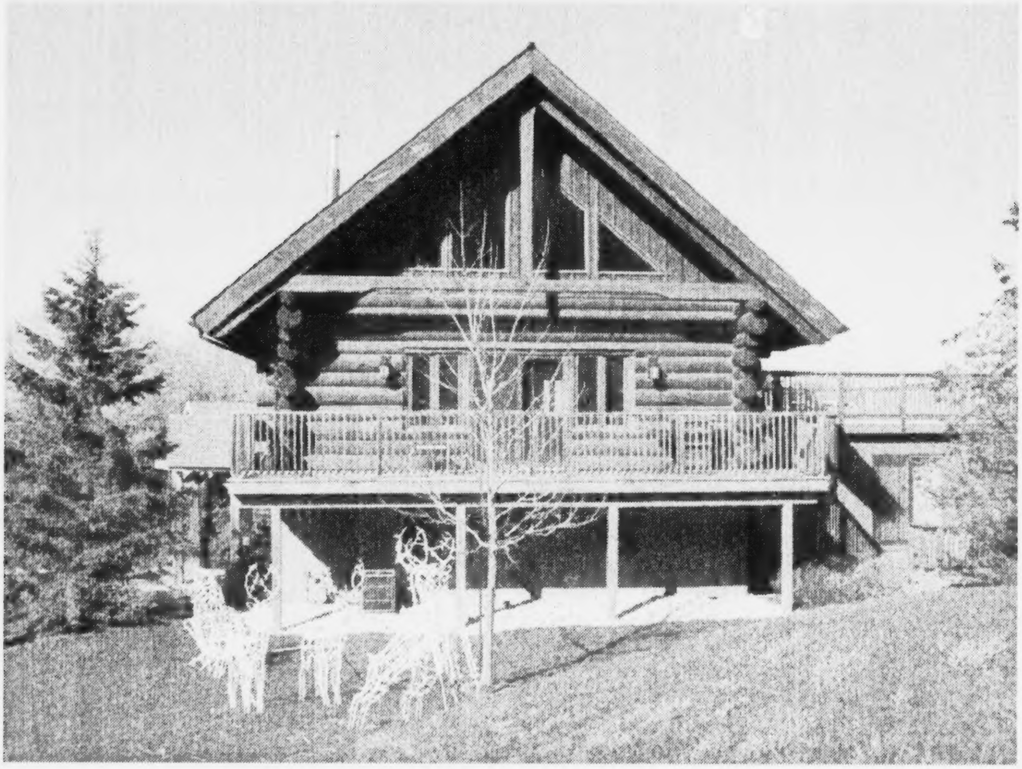

Figure 18:1
Log Construction
(photo credit: Tusia Designs)

Exercise #18-1

Read Section 9.37. Answer the following questions, then discuss your answers with your group.

1. What is the maximum horizontal spacing between fasteners joining two horizontal logs?

   a) 1200 mm

   b) 1800 mm

   c) 2400 mm

   d) No maximum provided that machined joints are provided.

OBC Reference(s): ______________

2. What must be done to portions of logs coming in contact with below grade masonry or concrete?

____

____

OBC Reference(s): ________________

3. What is the minimum required clearance between the header and the lintel log, to allow for settlement at a window opening, in a wall made of logs oriented in a vertical position?

   a) 13 mm for each 300 mm of opening height

   b) 25 mm

   c) 50 mm

   d) No minimum specified

OBC Reference(s): ________________

STOP

18.3 PARK MODEL TRAILERS

Section 9.39 applies to manufactured *buildings* used or intended to be used for *residential occupancy*, and designed and constructed in conformance with CAN/CSA-Z241 Series, "Park Model Trailers". The CSA Standards outline the minimum requirements for materials, products, equipment, and workmanship needed to ensure that park model trailers will have adequate:

- structural strength and rigidity;
- protection against corrosion, decay, insects, and similar destructive forces;
- protection against the hazards of fire;
- resistance to the elements; and
- durability and economy of maintenance.

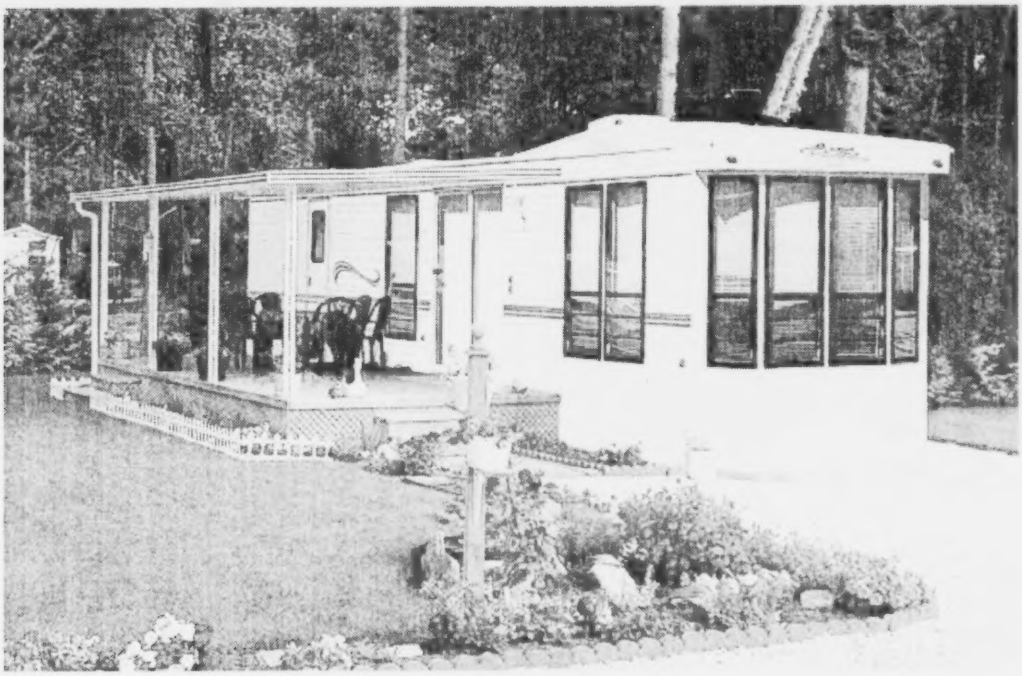

Figure 18:2
Park Model Trailer
(photo credit: General Coach (division of Citair Inc.))

Exercise #18-2

Read Section 9.39 and answer the following questions. Then discuss your answers with your group.

1. What are the anchorage requirements of Section 9.39 that apply to a contractor's trailer on a construction site?

____

____

____

____

OBC Reference(s): ________________

2. If a manufactured *building* intended to be used as a seasonal recreation *building* of *residential occupancy* is designed and constructed in conformance with the Standard CAN/CSA-Z241 Series, what are the Code requirements for its support and anchorage?

____

____

____

OBC Reference(s): ______________

3. Do the *foundation* provisions of Section 9.15 apply to park model trailers?

   a) Yes

   b) No

OBC Reference(s): ______________

18.4 COTTAGES

Section 9.36 applies to buildings of residential occupancy intended to be used as seasonal recreational buildings.

Buildings meeting this description must comply with all the requirements of Part 9 except for the exclusions listed in Article 9.36.2.1. An 'optional' exclusion for foundations is provided in Sentence 9.36.2.2.(1) that states that continuous foundation walls are not required but if they are provided they are required to meet the requirements of Part 9.

Exercise #18-3

Read Section 9.36 and answer the following questions. Then discuss your answers with your group.

1. What is the minimum size of a unreinforced unit masonry column constructed from hollow masonry units?

   a) 140 (d) x 390 (w) x 560 (h)

   b) 190 (d) x 390 (w) x 760 (h)

   c) 240 (d) x 390 (w) x 960 (h)

   d) 290 (d) x 290 (w) x 1160 (h)

   OBC Reference(s): ____________________

STOP **End of Module 18**

MODULE 19

FARM BUILDINGS

BUILDING STRUCTURAL – 2006

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19.0 Introduction 1

19.1 Objectives 1

19.2 What Is A Farm Building? 2

19.3 Code provisions for farm buildings 3

19.4 Farm Buildings - Supplementary Standard Sb-11 5

19.5 Manure Storage Tanks 8

19.0 INTRODUCTION

In this Module, we will review the structural issues and requirements of the Building Code relating to *farm buildings* and manure tanks.

19.1 OBJECTIVES

Upon completion of this Module participants will be able to:

- Identify what types of structures may be classified as *farm buildings*
- Apply the Code provisions to *farm buildings*
- Select structural member sizes for *farm buildings*
- Apply the requirements of Part 4 to manure storage tanks

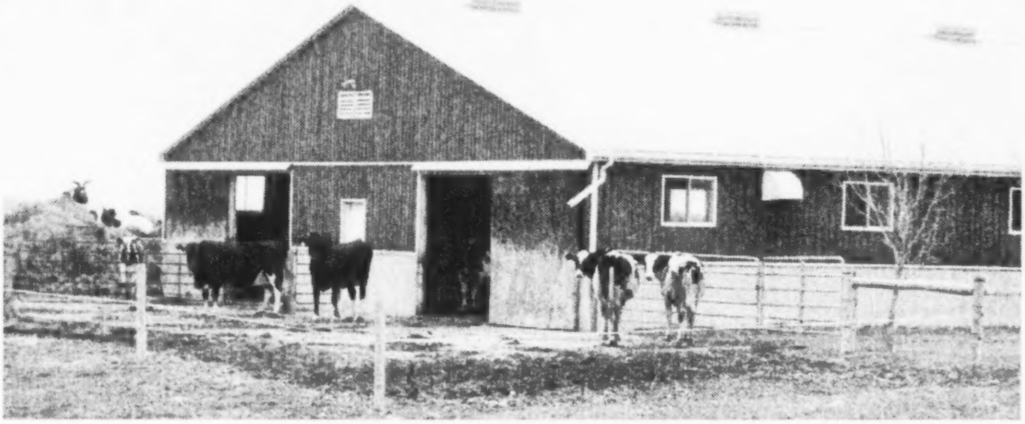

Figure 19:1
Farm Building
(photo credit: Tusia Designs)

19.2 WHAT IS A FARM BUILDING?

To understand the provisions of the Code to *farm buildings*, it is important to first become familiar with the applicable terminology from Article 1.4.1.2 of Division A:

- ***Farm building*** means all or part of a *building*,
  - (a) that does not contain any area used for *residential occupancy*,
  - (b) that is associated with and located on land devoted to the practice of farming, and
  - (c) that is used essentially for the housing of equipment or livestock or the production, storage or processing of agricultural and horticultural produce or feeds.
- ***Low human occupancy*** means, when applied to a *farm building*, an *occupancy* in which the *occupant load* is not more than one person per 40 m^2 of *floor area* during normal use.
- ***Occupant load*** means the number of persons for which a *building* or part of a *building* is designed.
- ***Floor area*** means the space on any *storey* of a *building* between exterior walls and required *firewalls*, including the space occupied by interior walls and *partitions*, but not including *exits*, *vertical service spaces* and their enclosing assemblies.

The National Farm Building Code has not been updated to reflect limit states design. See Division B Table 1.3.1.2 for the applicable edition of NFBC.

19.3 CODE PROVISIONS FOR FARM BUILDINGS

Guidance on the approach to the design of *farm buildings* is given in Article 1.3.1.2 of Division A.

Generally, a *farm building* must comply with the requirements of the CCBFC National Farm Building Code of Canada. However, depending on the *occupancy*, *building area* and *building height*, it may be permissible to make use of Supplementary Standard SB-11, "Construction of Farm Buildings".

Exercise #19-1

Read Article 1.3.1.2 of Division A.
With reference to the definitions in Division A, Article 1.4.1.2, answer the following questions then discuss the answers with your group.

1. For a one-storey *farm building* of *low human occupancy* with a *building area* of 650 m^2, where are the Code provisions found?

   a) CCBFC National Farm Code of Canada

   b) Supplementary Standard SB-11

   c) Either a) or b)

   d) Neither a) nor b)

   OBC Reference(s): ________________

2. For a two-storey *farm building* of *low human occupancy* with a *building area* of 500 m^2, where are the Code provisions found?

   a) CCBFC National Farm Code of Canada

   b) Supplementary Standard SB-11

   c) Either a) or b)

   d) Neither a) nor b)

   OBC Reference(s): ________________

3. What is the maximum allowable occupant load for a *farm building of low human occupancy*?

   a) 1 person per 39 m^2 of *floor area*
   b) 1 person per 40 m^2 of *floor area*
   c) 1 person per 41 m^2 of *floor area*
   d) None of the above

   OBC Reference(s): ________________

4. A *farm building* that will be used for the production of horticultural produce is planned to be a single *storey building*, with normal operations having 16 employees per shift.
   What is the minimum *floor area* necessary for the building to be classified as a *farm building* of *low human occupancy*?

   a) 2.5 m^2
   b) 640 m^2
   c) 656 m^2
   d) None of the above

   OBC Reference(s): ________________

STOP

19.4 FARM BUILDINGS - SUPPLEMENTARY STANDARD SB-11

As we have seen, the Code allows certain types of *farm buildings* to be designed using Supplementary Standard SB-11, "Construction of Farm Buildings".

It is important to fully understand Section 1 of SB-11, before applying any structural provisions of SB-11:

- As stated in Sentence 1.2.1.(1) of SB-11, the provisions of Part 9 of Division B are generally applicable to *farm buildings* of *low human occupancy*. For example, wind and roof loads for *farm buildings* would be determined using Subsection 9.4.2 of Division B.
- As stated in Sentence 1.3.1.(1) of SB-11, the structural design must conform to Section 9.4 of Division B. The member selection tables of SB-11 maybe used in lieu of 9.4.1.1(1)(c)(i).
- The member selection tables of SB-11 apply to *farm buildings* of *low human occupancy* only, as stated in Subsection 1.3.1 of SB-11.
- The member selection tables of SB-11 only address wood posts, joists, rafters, lintels, beams and wall studs. All other structural components must comply with Part 9. Where the limitations of Part 9 are exceeded, then the structural components must comply with Part 4.
- As stated in Article 9.4.1.1 of Division B, structural design will be required using Part 4, for many structural elements/connections.

It should also be noted, that when the CCBFC National Farm Building Code is used, there are provisions within that Code that may direct the designer to Parts 3, 4 and 9 of the Building Code. However, the subject matter of the CCBFC National Farm Building Code is beyond the scope of this course and the qualification exam.

Exercise #19-2

Read Supplementary Standard SB-11.
Answer the following questions, then discuss the answers with your group.
(For this exercise, assume that SB-11 applies to all *buildings*)

1. The floor joists in a 2-storey barn containing straw and hay are 38 mm x 184 mm. The *live load* is 2.8 kPa, and the wood to be used is ungraded.
   What is the maximum allowable span of the floor joists, if the barn has *low human occupancy*?
   a) 2.4 m
   b) 3.0 m
   c) 3.6 m
   d) 4.2 m
   OBC Reference(s): ________________

2. The roof rafters of a *farm building* of *low human occupancy* have a span of 4200 mm and a spacing of 600 mm. If the wood used is No. 3 spruce, and the specified roof snow load is 2.0 kPa, what is the minimum required rafter size?
   a) 38 x 140
   b) 38 x 235
   c) 38 x 286
   d) 76 x 305
   OBC Reference(s): ________________

3. 152.4 mm x 203.2 mm wood posts of ungraded lumber are to be used in a *farm building* of *low human occupancy* that has a width of 12.1 m and a wall height of 4.2 m. The 1-in-10 year wind velocity pressure has been determined to be 0.35 kPa and the *building* will be knee braced.
   What is the maximum post spacing if the roof load is 2.4 kPa?

   a) 2.4 m

   b) 3.6 m

   c) 4.8 m

   d) Ungraded lumber is not allowed

   OBC Reference(s): ____________________

4. If round posts were to be used instead of the posts in Question 4 above, what would be the minimum equivalent diameter?

   a) 101.6 mm

   b) 177.8 mm

   c) 203.2 mm

   d) 222.3 mm

   OBC Reference(s): ____________________

5. For a *farm building*, Table 1.3.3.L of SB-11 has been used to select the roof rafters. The rafters span 5.0 metres, are spaced at 600 mm, and have been determined to be 76.2 mm x 304.8 mm wood.
   What is the Code requirement for the connection of the rafters to the ridge board?
   a) 3 toe nails of minimum 82 mm length
   b) 6 toe nails of minimum 82 mm length
   c) 6 toe nails of minimum 164 mm length
   d) Connections must be designed using Part 4, Division B

   OBC Reference(s): ____________________

   ____

   ____

STOP

19.5 MANURE STORAGE TANKS

According to Division A, Sentence 1.3.1.3.(5), the Code provisions for manure storage tanks are given in Subsection 4.4.5 of Division B.

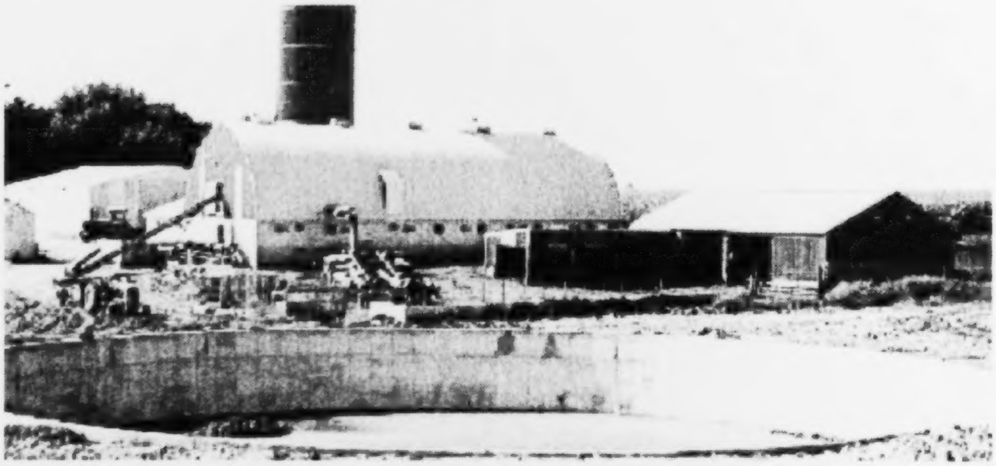

Figure 19:2
Manure Storage Tank

Exercise #19-3

Read Subsection 4.4.5 of Division B.
Answer the following question, then discuss the answers with your group.

1. Which of the following statements concerning manure storage tanks are false?

   a) Manure storage tanks must be supported on competent *soils* free of organic material, or on compacted granular *fill* above such competent *soil*.

   b) With the exception of the provisions of Article 4.4.5.1, the design provisions for manure tanks are given in the National farm Code of Canada.

   c) Concrete in manure storage tanks shall have a specified strength of 32 MPa, with a water/cement ratio of 0.45 or more, and made using Type 50 cement.

   d) It is a Code requirement that manure storage tanks do not leak.

   OBC Reference(s): ______________

STOP End of Module 19

MODULE 20

RENOVATIONS – PART 11

BUILDING STRUCTURAL – 2006

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20.2 Application of Part 11 2
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20.4 Performance Level Evaluation 6
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20.0 INTRODUCTION

In this Module, we will learn when Part 11 of the Code applies regarding structural assessments and how the Code deals with situations where the *performance level* regarding structural systems may be affected by renovations.

20.1 OBJECTIVES

Upon completion of this Module participants will be able to:

- Explain the applicability of Part 11 to *building* structures
- Recognize the terminology and definitions in Part 11
- Apply the allowable structural *compliance alternatives* (CAs) to requirements in Parts 3, 4 and 9 of the Code.

20.2 APPLICATION OF PART 11

For new construction, applying Building Code requirements regarding structural sufficiency is relatively straightforward. Design loads and design procedures are well established and the Code makes provision for unusual structures that may require special consideration.

For the renovation of an existing *building*, however, the cost of increasing the strength of an existing structure may exceed the potential benefits.

The Canadian Building Digest article entitled "Applying Building Codes to Existing Buildings", which is Publication No. CBD-230 prepared by the Institute for Research in Construction states:

> "where a building has been standing for many years, and its condition or its relationship to adjacent buildings has not changed significantly, one may consider the building to be field tested. If a roof has withstood the effect of snow and wind for 50 or 60 years and shows no signs of distress, one may reasonably assume that it will continue to provide adequate service. The same may be assumed for walls in relation to wind loads. Earthquake loads are more difficult to assess on this basis because of their irregular occurrence. Nevertheless, some assessment may be made in the light of the recorded seismic activity of the area where the building is located".

When renovating existing *buildings*, some Code requirements that apply for new construction may not be appropriate for the special situations involved. Part 11 was written to ensure that life safety systems and *building* performance are maintained during the conversion and re-use of existing *buildings*. Part 11 of the OBC provides a practical, reasonable and flexible approach to renovation.

Sentence 11.1.1.1.(1) refers to Subsection 1.1.2 of Division A. Articles 1.1.2.6 and 1.1.2.7 of Division A state the circumstances under which Part 11 may be used.

Exercise #20-1

Read Division B, Sentence 11.1.1.1.(1) and Division A, Articles 1.1.2.6 and 1.1.2.7.
Complete the following exercise, then discuss your answers with your group.

1. You are asked to determine the building code requirements for the proposed renovation of a 3-storey single-family house that was built in the 1930s, for the purpose of creating 3 dwelling units. Which of the following applies?

   a) Part 4
   b) Part 9
   c) Part 11
   d) National Farm Building Code of Canada

   OBC Reference(s): ________________

2. A *building* constructed in 1987 is to be renovated. An addition was made to the *building* last year, and the renovation will affect both the original *building* and the recent addition. What part of the Building Code applies to the structural design of the renovation?

   a) Part 4
   b) Part 9
   c) Part 11
   d) National Farm Building Code of Canada

   OBC Reference(s): ________________

STOP

20.3 PERFORMANCE LEVEL AND BUILDING SYSTEM

Division A, Article 11.4.1.2 says:

> Performance level means the level of performance under which all or part of an existing *building* functions with respect to its building systems.

Division B, Article 11.1.1.2 says:

> Building system means a combination of elements or components that form a complete major division of *construction* in the design of a *building* or part of a *building*, including a structural or framing system, a waterproofing system, a *drainage* system, an *exterior cladding* system, a roofing system, a window system, a *partition* system, a corridor system, a stair system, a fire alarm and detection system, a sprinkler system or a heating, ventilation or *air-conditioning* system, a *foundation* system, a standpipe and hose system, a flooring system, a *plumbing system*, a *sewage system* or an electrical system.

Note that a structural or framing system is part of a *building system*.

It is a basic requirement of Part 11 that a renovation does not reduce the *performance level* of a *building* or part of a *building*.

Exercise #20-2

With reference to the definitions noted above, read subsection 11.3.1.
Complete the following exercise, then discuss your answers with your group.

1. An existing *building* supporting a given use is considered to provide a certain *performance level*. What happens to the *performance level* if a renovation project adversely affected the existing framing system of the *building*?

   a) *Performance level* is reduced

   b) *Performance level* stays the same

   c) *Performance level* is increased

   d) All of the above

2. What is the fundamental *performance level* requirement of Part 11 that applies to a *building system* subsequent to material alteration or repair?

   ____

   ____

   OBC Reference(s): ______________

STOP

20.4 PERFORMANCE LEVEL EVALUATION

Article 11.4.1.1 states that the *performance level* of a *building* after construction shall not be less than the *performance level* of the *building* prior to construction.

Subsection 11.4.2 must be used in order to determine if there would be a reduction of *performance level* as a result of the proposed renovation. In applying the provisions of this subsection, it is important to understand the meanings of such defined terms as *major occupancy* and *occupant load*. These definitions are found in Division A of the Code.

Exercise #20-3

Read Sentence 11.4.1.1.(2) and Article 11.4.2.1. Answer the following questions, then discuss your answers with the group.

1. A 2-storey historical house with a *basement* and having a floor area of 300 m^2 at each floor is being converted into a restaurant.
   For structural purposes, how will the *performance level* be affected?

   a) *Performance level* is reduced
   b) *Performance level* stays the same
   c) *Performance level* is increased
   d) Part 11 does not apply

OBC Reference(s): ________________

2. A manufacturing *building* with a flat roof was constructed in 1985. It is proposed to place a large *air-conditioning unit* on the roof, and to suspend a new ceiling system from the roof joists. The original *building* structure was designed with reserve load capacity. How does the proposed renovation affect the *performance level* of the *building*?

   a) *Performance level* is reduced

   b) *Performance level* stays the same

   c) *Performance level* is increased

   d) None of the above

OBC Reference(s): ________________

3. In an existing 4-storey *building* to be renovated, 75 m^2 of floor area on an upper floor is to be converted from office space to a cafeteria dining area. The *building* is more than 5 years old. Assuming that the *building* structure is adequate to support specified office *live loading* on the floors, is the proposed renovation acceptable to the Code without structural modifications? Why?

   a) Yes

   b) No

   c) Yes, with certain restrictions

   Reasons and OBC Reference(s):

   ____

   ____

   ____

STOP

20.5 COMPENSATING CONSTRUCTION

If it is determined that the *performance level* would be reduced by a renovation, Sentence 11.4.1.1.(3) requires that compensating *construction* be provided in conformance with Subsection 11.4.3.

Keep in mind that Sentence 11.4.3.1.(3) states that the required compensating *construction* applies to the existing *building systems* that are adversely affected by the proposed *construction*.

This would include analysis of existing columns, loadbearing walls, floors, roofs and foundations if it were determined that there would be a reduction of *performance level* as a result of the proposed renovation.

EXERCISE #20-4

Read Articles 11.4.3.1 and 11.4.3.2 of the Building Code. Complete the following exercise then discuss your answers with the group.

1. A proposed renovation will increase the *occupant load* of a multi-story *building* by 20%, however the *live load* on floors according to Table 4.1.5.3 are such that the factored floor loads are within the safe factored floor resistances. What must be done to comply with the structural requirements of the Code?

   a) Nothing – renovation may proceed without compensating construction

   b) The floors must be structurally reinforced.

   c) The increase in *occupancy load* is not allowed.

   d) The *building* must be demolished.

   OBC Reference(s): ______________

2. Consider the *building* described in Question 2 of Exercise #20-3. An engineering analysis of the roof has determined that the installation of the ceiling and the mechanical equipment would reduce the *performance level*. What measures must be taken to allow the renovation to proceed?

   a) Nothing – renovation may proceed without compensating construction

   b) The portion of the structure affected must be reinforced to support the new *dead loads*, accounting for the snow loads (including drifts) stated in the 2006 Ontario Building Code.

   c) The portion of the structure affected must be reinforced to support the new *dead loads*, accounting for the snow loads (including drifts) stated in the Code in effect at the time of the original *building*'s design.

   d) The entire roof structure must be reinforced to account for the snow loads (including drifts) as stated in the 2006 Ontario Building Code.

   OBC Reference(s): ________________

STOP

20.6 COMPLIANCE ALTERNATIVES

Article 11.5.1.1 permits a *compliance alternative* (CA) to be substituted for a requirement contained in Part 4 of the Code, where the *Chief Building Official* is satisfied that compliance with the requirement is impracticable because:

(a) of structural or *construction* difficulties, or

(b) it is detrimental to the preservation of a *heritage building*

A *compliance alternative* for a structural requirement contained in Part 9 may be substituted, without satisfying the *Chief Building Official* that compliance with the requirement is impracticable.

Exercise #20-5

Read Article 11.5.1.1 and complete the following exercise. Then discuss your answers with your group.

1. Interior renovations for an existing hospital constructed in 1969 are planned to enlarge the emergency department. The *building* is such that S(0.2) exceeds 0.12, and is therefore not exempt under Sentence 4.1.8.1.(1). The structural engineer has determined by analysis that the ULS factored resistance of certain components of the SFRS is less than the factored loads determined using Subsection 4.1.8. What must the engineer do?

   a) Do nothing

   b) Reinforce the structure to comply with current Part 4 requirements

   c) Advise the client that the renovation is not feasible

   d) Ask for a special Code exemption from the *Chief Building Official*

   OBC Reference(s): ________________

2. For the *building* in question 1, the architect has asked the structural engineer to do a review of the existing handrails, and ensure that they comply with Building Code structural requirements.

   The engineer has determined that the handrails in *exit* stairs and their supports do not withstand the loading values specified in Sentence 3.4.6.4.(9).

   What should the engineer do?

   ____

   ____

   OBC Reference(s): ________________

3. In renovating an existing Part 9 house, it is desired to corbel the exterior brick to match the existing corbelling. However, it has been determined that the existing corbels do not comply with Article 9.20.12.3. Which of the following describe the minimum Code requirements for the new brick work?

   a) New corbels must fully comply with Article 9.20.12.3

   b) Existing corbels must be rebuilt to comply with Article 9.20.12.3

   c) New corbels may be built to match existing corbels

   d) New corbels may be built to match existing corbels, provided they are structurally adequate for the proposed use

   OBC Reference(s): ________________

Figure 20:1
High Density File Storage in an Existing Building

4. It is proposed to install high-density file storage in an existing office *building*, similar to that shown in Figure 20:1. An engineer has found that the floor is not adequate to support the proposed file loading.

   - Under what authority should the engineer take remedial measures?
   - Which *compliance alternatives* should the engineer use?

Authority: ______________________________

OBC Reference(s): ______________________

Compliance Alternative: ________________

OBC Reference(s): ______________________

STOP End of Module 20

Module 2 Scope and General Requirements	
Exercise Number	**Answer**
Exercise 2-1	Question 1 Answers a. Sentence 3.7.4.14.(1) or Subclause 3.8.3.8.(1)(d)(iv) b. Sentence 4.3.5.1.(1) c. Sentence 9.15.4.9.(1)
Exercise 2-2	Question 1 **Part 9** (Ref: Div. A, Article 1.1.2.4) Question 2 **Part 9** (Ref: Div. A, Article 1.1.2.4) Question 3 **Parts 3 and 4** (ref Div. A Article 1.4.1.2)
Exercise 2-3	Question 1 **Yes** and **Yes**, Per Clause 1.3.1.1.(1)(i) and Clause 1.1.2.2.(2)(c) Question 2 **Yes** and **Yes**, Per Div. A, Clause 1.3.1.1.(1)(a) and Div. A, Clause 1.1.2.2.(2)(c), Question 3 **No** and **No**, Per Div. A, Clause 1.3.1.1.(1)(d) Question 4 **NO** to designated structure, but **YES** to Part 4 as per Div. A Clause 1.3.1.1.(1)(e), Div. A, Clause 1.1.2.2.(2)(c), Clause 1.1.2.2.(5), Div. B, Sentence 3.15.3.1.(1).
Exercise 2-4	Question 1 **Answer is b),** See column 4 of Table 1.3.1.2 in Division B Question 2 **Answer is a),** In accordance with Div. A, Sentence 1.5.1.2.(1), the Code provisions govern.
Exercise 2-5	Question 1 a) Rain (columns 7 and 8) b) Snow (columns 12 and 13) c) Hourly Wind Pressures (columns 14 and 15) d) Earthquake Data (columns 16 to 20) e) Temperatures (columns 2 to 6)

	Question 2 **Answer is a)** Question 3 **Answer is c),** from Table 1.1 of SB- 1

MODULE 3 STRUCTURAL DESIGN USING DIVISION B, PART 4

Exercise 3-1	Question 1 **Answer = d),** as per Sentences 4.1.1.3.(1) to (4) Question 2 **Answer = b),** as per Sentence 4.1.1.3.(3) Question 3 **Answer = c),** as per Sentence 4.1.1.4.(2) Question 4 **Answer = b),** as per Sentence 4.1.1.4.(3).
Exercise 3-2	Question 1 a. Answer = "S", as per Sentence 4.1.2.1(1) b. Answer = "D", as per Sentence 4.1.2.1(1) and Clause 4.1.4.1(1)(c) c. Answer = "D", as per Sentence 4.1.2.1(1) & Clause 4.1.4.1.(a) d. Answer = "E", as per Sentence 4.1.2.1(1) e. Answer = "H" as per Sentence 4.1.2.1(1) f. Answer = "L", per Sentence 4.1.2.1(1) g. Answer = "T", as per Sentence 4.1.2.1(1) h. Answer = "W", as per Sentence 4.1.2.1(1) i. Answer = "D", as per Sentences 4.1.2.1(1) and 4.1.4.1(1) Question 2 **Answer = b),** as per Article 4.1.2.2
Exercise 3-3	Question 1 a. Importance category = Normal b. With reference to the definition of low human occupancy in Div. A, Article 1.4.1.2, importance category = "low" c. Importance category = Normal d. Importance category = High e. Importance category = Post-disaster f. Importance category = Normal g. Importance category = Normal, provided building does not contain a "control centre", in which case it would be considered "Post-disaster"

Exercise 3-4	Question 1 **Answer = b)**, as per Sentence 4.1.3.5.(1) Question 2 **Answer = d),** as per Sentence 4.1.3.5(5) Question 3 **Answer = d)** Question 4 **Answer = d**), as per Sentence 4.1.3.4.(1) Question 5 **Answer = b),** as per Sentence 4.1.3.3.(2) Question 6 **Answer = d)**, as per Sentence 4.1.3.6.(3)
Exercise 3-5	Question 1 **Answer = c)**, as per Sentence 4.1.3.2.(1) Question 2 **Answer = c)**, from Table 4.1.3.2 Question 3 **Answer = c)**, from Table 4.1.3.2 Question 4 **Answer =b)**, as per Sentence 4.1.3.2.(6) Question 5 **Answer = b)**, as per OBC 4.1.3.4 Question 6 **Answer =d),** from Table 4.1.3.2 Question 7 **Answer = c),** See the definition of "effects" in Clause 4.1.3.1.(1)(j) Question 8 a. Factored overturning moment = 1.5*20 = 30 kN.m, as per Sentence 4.1.3.2.(3) b. Stabilizing moment = 0.9*40 = 36 kN.m, from Sentence 4.1.3.2.(4) c. Yes, Since factored stabilizing moment > factored overturning moment

Exercise 3-6	Question 1 **Answer = c),** as per Subsection 4.3.2 and Table 1.3.1.2 Question 2 **Answer = c).** Sentence 4.3.1.3.(1) refers the user to Articles 9.3.2.9, 9.12.1.1 and 9.15.5.1 in termite-infested areas Question 3 **Answer = d),** as per Sentence 4.3.5.1.(1) Question 4 **Answer = b),** as per Sentence 4.1.1.4.(2)

MODULE 4 DEAD LOADS AND LIVE LOADS DUE TO OCCUPANCY

Exercise 4-1	Question 1 **Answer = c)**, as per Article 4.1.4.1 Question 2 **Answer = c)**, as per Sentences 4.1.4.1.(2) and 4.1.4.1(3) Question 3 **Answer = a)**, as per Sentence 4.1.4.1(5) Question 4 **Answer = b)**, as per Sentence 4.1.4.1(6)
Exercise 4-2	Question 1 a. 4.8 kPa (Retail and wholesale areas) b. 4.8 kPa c. If a recreation area with no assembly, then LL=3.6 kPa. If a Gymnasium (assembly area), 4.8 kPa applies d. 4.8 kPa e. 2.9 kPa for reading rooms, 7.2 kPa for book stacks f. 1.0 kPa g. 4.8 kPa since dining area h. 1.9 kPa i. 1.9 kPa j. 4.8 kPa Question 2 **Answer = b)**, as per Sentence 4.1.5.1(1) Question 3 **Answer = b)**, as per Sentence 4.1.5.2.(2) or 4.1.5.1.(2)

	Question 4 **Answer = c)**, as per Sentence 4.1.5.3.(1) & Table 4.1.5.3, and Sentence 4.1.5.10.(1) & Table 4.1.5.10 Question 5 **Answer = d)**, as per Article 4.1.5.10.(1) Question 6 **Answer = c)**, as per Article 4.1.5.13 Question 7 **Answer = b)**, as per Sentence 4.1.5.5.(2) Question 8 **Answer = d)**, as per Sentence 4.1.5.7.(1)
Exercise 4-3	Question 1 **Answer = b)**, as per Sentence 4.1.5.9.(3) Question 2 **Answer = c)**, as per Sentence 4.1.5.9.(2) Question 3 **Answer = d)**, as per Sentence 4.1.5.9.(1) Question 4 **Answer = c)**, as per Sentence 4.1.5.9.(4)
MODULE 5 SNOW AND RAIN LIVE LOADS	
Exercise 5-1	Question 1 **Answer = a)**, from Table 1.2 of SB-1 Question 2 From Sentence 4.1.6.2(1): a. Ground snow load (i.e. location of building) b. Wind Exposure c. Roof Slope d. Roof Shape (and associated snow accumulation) e. Use and occupancy of building (through the use of an importance factor)
Exercise 5-2	Question 1 **Answer = d)**, from Table 4.1.7.1, Table 4.1.2.1.B and the definition of a post-disaster building in Division A, Article 1.4.1.4

	Question 2 **Answer = b)**, from Table 4.1.7.1
Exercise 5-3	Question 1 **Answer = b)**, as per Article 4.1.6.2 Question 2 **Answer = c),** as per Sentence 4.1.6.2.(4)(b)
Exercise 5-4	Question 1 **Answer = b)**, as per Sentence 4.1.6.2.(2)(b) Question 2 **Answer = a)**, as per Sentences 4.1.6.2.(3) and (4) Question 3 **Answer = c)**, as per Clause 4.1.6.2.(2)(a)
Exercise 5-5	Question 1 **Answer = d),** as per 4.1.6.2.(6)(b) Question 2 **Answer = c),** as Per Sentence 4.1.6.2.(7)
Exercise 5-6	Question 1 **Answer = c),** as per Sentence 4.1.6.2.(8) Question 2 **Answer = c)**, as per Sentence 4.1.6.2.(8)
Exercise 5-7	Question 1 **Answer = d)** Question 2 **Answer = b),** as per Table 4.1.5.3
Exercise 5-8	Question 1 **Answer = d)**, as per Sentence 4.1.6.3.(2) Question 2 **Answer = d),** as per Sentence 4.1.6.3.(2) Question 3 **Answer = d)**, as per Sentence 4.1.6.3.(2)
Exercise 5-9	Question 1 **Answer = b)**, as per Sentence 4.1.6.4.(1)

	Question 2 **Answer = a)**, as per Sentence 4.1.6.4.(1) Question 3 **Answer = c),** as per Sentences 4.1.6.4(1) and 4.1.6.2.(1) Question 4 **Answer = d),** as per Sentences 4.1.6.4(1) and 4.1.6.2.(1)
Module 6 Wind Loads	
Exercise 6-1	Question 1 **Answer = b)**, as per OBC 4.1.7.2.(1) Question 2 **Answer = a)**, as per Sentence 4.1.7.2.(2) Question 3 **Answer = b)**
Exercise 6-2	Question 1 **Answer = b),** from Table 4.1.2.1 Question 2 **Answer = a),** from Table 4.1.7.1
Exercise 6-3	Question 1 **Answer = c)**, as per Table 2-1 of SB-1 Question 2 **Answer = c)**, as per Table 2-1 of SB-1
Exercise 6-4	Question 1 **Answer = b)**, as per Clause 4.1.7.1.(5)(b) Question 2 **Answer = d)**, as per Sentence 4.1.7.2.(1) Question 3 **Answer = c)**, as per Clause 4.1.7.1.(5)(b)
Exercise 6-5	Question 1 **Answer = b)**, as per Clause 4.1.7.1.(6)(c) Question 2 **Answer = c)**, as per Clause 4.1.7.1.(6)(b)

	Question 3 **Answer = a)**, as per Clause 4.1.7.1.(6)(a)
Exercise 6-6	Question 1 **Answer = b)**, as per Sentence 4.1.7.1.(1) Question 2 **Answer = a)** Question 3 **Answer = d)**, as per Article 4.1.7.1.(2)
Exercise 6-7	Question 1 **Answer = c)**, as per Article 4.1.7.1.(3)
Exercise 6-8	Question 1 **Answer = c)**, as per Article 4.1.7.1
Exercise 6-9	Question 1 **Answer = b)**, as per Sentence 4.1.7.3.(1)
Module 7 Earthquake Loads	
Exercise 7-1	Question 1 Site Class C, as per Sentence 4.1.8.4.(3) Question 2 Site Class F as per Notes to Table 4.1.8.4.A Question 3 From Table 4.1.8.4.A: Site Class = D From Table 4.1.8.4.B (interpolation between 0.25 and 0.5): F_a = 1.28 From Table 4.1.8.4.C: F_v = 1.4 Question 4 For T ≤ 0.2 s, S(T) = 0.38 g For T = 0.5 s, S(T) = 0.22 g For T = 1.0 s, S(T) = 0.118 g For T = 2.0 s, S(T) = 0.034 g For T ≥ 4.0 s, S(T) = 0.017 g Question 5 No, as per Division B, Sentence 4.1.8.1.(1)

Exercise 7-2	Question 1 Sentence 4.1.8.6.(2) states that structures not classified as irregular according to Sentence 4.1.8.6.(1) may be considered regular. Question 2 a. Type 2 Weight (mass) irregularity - the second floor has a mass equal to 170% of the third floor b. Type 4 In-Plane Discontinuity in Vertical Lateral-Force-Resisting Element - the opening at the ground floor level may reduce the lateral stiffness of the building's shear wall c. Type 5 Out-of-Plane Offsets - the columns are not located directly above one another d. Type 1 Vertical Stiffness Irregularity - the sixth floor has a stiffness of 60% of that of the fifth floor. Type 6 Discontinuity in Capacity (Weak Storey) - does not occur since the average storey shear strength of the sixth, seventh and eighth floors is not larger than the storey shear of the fifth floor.
Exercise 7-3	Question 1 a. Clause 4.1.8.7.(1)(a) permits the use of the equivalent static force procedure b. The structure has a Type 7 irregularity and therefore dynamic analysis procedure is required [Clause 4.1.8.7.(1)(c))] c. The equivalent static force procedure may be used [Clause 4.1.8.7.(1)(b)] d. Dynamic analysis is required, since the structure has a Type 6 irregularity and is more than 20 m in height [Clause 4.1.8.6.(1)(c))]
Exercise 7-4	Question 1 a. If the components of the SFRS are oriented along a set of orthogonal axes, Clause 4.1.8.8.(1)(a) permits an independent application of earthquake forces. Similarly, Clause 4.1.8.8.(1)(b) would permit independent application of forces if the SFRS are not along orthogonal axes. b. Independent application of earthquake forces along any two orthogonal axes is permitted by Clause 4.1.8.8.(1)(b) c. If the components of the SFRS are oriented along a set of orthogonal axes, Clause 4.1.8.8.(1)(a) permits an independent application of earthquake forces. d. Independent application of earthquake forces is not permitted by Clause 4.1.8.8.(1)(c)

Exercise 7-5	Question 1 R_d = 1.5 R_o = 1.5 Question 2 For the short period spectral design acceleration value of 0.2, Table 4.1.8.9. does not limit the height of the SFRS, however, for the long period spectral design acceleration value of 0.35, Table 4.1.8.9. limits the height of the SFRS to 15 m. - where there is a conflict between restrictions, the most stringent restriction governs i.e., 15 m. Question 3 a. No height limit for SFRS - "shear walls", and R_d and R_o are correct. b. Height limit for SFRS - "shear walls" is correct, however, R_d and R_0 are for ductile shear walls (i.e., question does specify if the shear walls are ductile or moderately ductile) c. Height limit for SFRS is 30 m - "shear walls", and the R_d = 1.5, R_0 = 1.3 Question 4 R_d = 1.5 R_o = 1.3 This SFRS is not permitted by column #7 of Table 4.1.8.9. Question 5 For reinforced masonry shear walls with moderate ductility: a. R_d = 2 b. R_o = 1.5 c. SFRS height limit of 40m For unreinforced masonry shear walls: d. R_d = R_0 = 1 e. SFRS is not permitted by Column #8 of Table 4.1.8.9 Question 6 From column #3 of Table 4.1.8.9. the R_0 = 1.3
Exercise 7-6	Question 1 The h_n for the structure is 5+3.5+3.5+3.5+3.5=19.0 m - For steel moment frames, T_a = 0.085(19)3/4=0.774 s - For concrete moment frames, T_a=0.075(19)3/4=0.683 s - For other moment frames, T_a=0.1(5)=0.5 s

Question 2
From Division B, Table 4.1.8.4.A.
Site Class = D
From Table 1.2, in SB-1
$S_a(0.2) = 0.12$
$S_a(0.5) = 0.075$
$S_a(1.0) = 0.038$
$S_a(2.0) = 0.011$

From Division B, Table 4.1.8.4.B
$F_a = 1.3$

From Division B, Table 4.1.8.4.C
$F_v = 1.4$

Design spectral acceleration values S(T):
$S(0.2) = F_aS_a(0.2) = 1.3 \times 0.12 = 0.156$
$S(0.5) =$ smaller of
$F_vS_a(0.2) = 1.4 \times 0.12 = 0.168$, or
$F_aS_a(0.5) = 1.3 \times 0.075 = 0.098$
use 0.098
$S(1.0) = F_vS_a(1.0) = 1.4 \times 0.038 = 0.053$
$S(2.0) = F_vS_a(2.0) = 1.4 \times 0.011 = 0.015$
$S(\geq 4.0) = F_vS_a(2.0)/2 = 1.4 \times 0.011 / 2 = .008$

Question 3
Step 1: calculate the short and long period spectral design acceleration triggers
short: IEFaSa(0.2) = 1.0 X 1.3 X 0.12 = 0.156

long: IEFvSa(1.0) = 1.0 X 1.4 X 0.038 = 0.053

From Division B, Table 4.1.8.9.
Column 4 - no limit to height of building
Column 8 - no limit to height of building
$R_d = 5$
$R_0 = 1.5$

Question 4
In question #1 we calculated Ta = 0.774 s

$S_a(0.2)/S_a(2.0) = 0.12 / 0.011 = 10.9$

From Division B, Table 4.1.8.11.
Column 3, $M_v = 1$
interpolation between columns 5 and 8, J = 0.945

Question 5

Question 6 Step 1 - complete computation table Storey	Level (x)	h(x) (m)	W(x) (kN)	h(x) X W(x) (kN m)
Grnd	*1*	*5.0*	*13,000*	*65,000*
Second	*2*	*8.5*	*10,000*	*85,000*
Third	*3*	*12.0*	*10,500*	*126,000*
Fourth	*4*	*15.5*	*10,000*	*155,000*
Fifth	*5*	*19.0*	*14,000*	*266,000*
			$\sum_{i=1}^{n} W_i h_i$	*697,000*

Determine W = 13,000 + 10,000 + 10,500 + 10,000 +13,000 = 57,500 kN

since the Rd = 5 and is greater than 1.5:

$$V_{maximum} = \frac{\frac{2}{3} S(0.2) I_E W}{R_d R_o} = \frac{\frac{2}{3} \times 0.12 \times 1.0 \times 57{,}500}{5 \times 1.5}$$

$$= 613.33 kN$$

$$V_{minimum} = \frac{S(2.0) M_v I_E W}{R_d R_o} = \frac{0.011 \times 1 \times 1 \times 57{,}500}{5 \times 1.5}$$

$$= 84.33 kN$$

{S(Ta) was calculated as 0.774 s} From Division B, Sentence 4.1.8.4.(6) we interpolate the design spectral acceleration value of S(T) between the values for S(0.5) and S(1.0). These values have been calculated in question #2.

S(0.5) = 0.098
S(1.0) = 0.053
interpolation for S(0.774) = 0.073

$$V = \frac{S(T_a) M_v I_E W}{R_d R_o} = \frac{0.073 \times 1 \times 1 \times 57{,}500}{5 \times 1.5}$$

$$= 559.67 kN$$

Step 2 - calculate Ft

Ft = 0.07TaV when Ta is > 0.7 and < 3.6
Therefore, Ft = 0.07 X 0.774 X 559.67 = 30.33 kN

Step 3 - complete distribution table

Level (x)	V - F_t (kN)	$W_x h_x$	$\frac{W_x h_x}{\sum_{i=1}^{n} W_i h_i}$	Force (x)
1	529.34	65,000	0.093	49.23
2	529.34	85,000	0.122	64.58
3	529.34	126,000	0.181	95.81
4	529.34	155,000	0.222	117.51
5	529.34	266,000	0.382	202.21 + 30.33 = 232.54

Question 7

Storey Shear	
5th	232.54 kN
4th	232.54+117.51=350.05 kN
3rd	232.54+117.51+95.81=445.86 kN
2nd	232.54+117.51+95.81+64.58=510.44 kN
Grd	232.54+117.51+95.81+64.58+49.23=559.67 kN

Exercise 7-7

Step One

Level (x)	Storey Shear (kN)	Height h(x)
1	559.67	5
2	510.44	8.5
3	445.86	12
4	350.05	15.5
5	232.54	19

Step Two

$h_{40\%}$=0.6 X 19.0 = 11.4 m

Step Three

Level (x)	J	J_x
1	0.945	*0.969*
2	0.945	*0.986*
3	0.945	*1.0*
4	0.945	*1.0*
5	0.945	*1.0*

Step Four

Level (x)	J_x	F (kN)	h_i - h_x	F(h_i - h_x)
1	.969	559.67	*5-0=5*	*2,711.6 kNm*
2	.986	510.44	*8.5-0=8.5*	*4,278.0 kNm*
3	1.0	445.86	*12-0=12*	*5,350.3 kNm*
4	1.0	350.05	*15.5-0=15.5*	*5,425.8 kNm*
5	1.0	232.54	*19-0=19*	*4,418.3 kNm*
			$\sum_{i}^{n} F_i(h_i - h_x)$	*22,184 kNm*

Therefore the M_x at the base is:
22,184 X .969 = 21,496 kNm

Level (x)	J_x	F (kN)	h_i - h_x	F(h_i - h_x)
3	1.0	445.86	*12-12=0*	*0 kNm*
4	1.0	350.05	*15.5-12=3.5*	*1,225.2 kNm*
5	1.0	232.54	*19-12=7*	*1,627.8 kNm*
			$\sum_{i}^{n} F_i(h_i - h_x)$	*2,853 kNm*

Therefore the M_x at level 3 is: 2,853 X 1.0 = 2,853 kNm

Exercise 7-8	Answers in Text

Exercise 7-9

From Article 4.1.8.5.

$I_E = 1.0$ (normal)

From Table 4.1.8.9.

$R_d = 1.5$

$R_o = 1.3$

From Sentence 4.1.8.13.(2) multiply lateral deflections by R_dR_o/I_E

$R_dR_o/I_E = (1.5 \times 1.3)/1.0 = 1.95$

Location	Calculated Deflection	Modified Deflection
BLDG 1 Second Storey	15 mm	29.25 mm
BLDG 1 Third Storey	40 mm	78 mm
BLDG 1 Roof	75 mm	146.25 mm
BLDG 2 Roof	75 mm	146.25 mm

Location	Modified Deflection	Interstorey Deflection ($0.025h_s$)	Maximum Lateral Deflection at each Location
BLDG 1 Second Sty	29.25 mm	100 mm	129.25 mm
BLDG 1 Third Sty	78 mm	100 mm	178 mm
BLDG 1 Roof	146.25 mm	100 mm	246.25 mm
BLDG 2 Roof	146.25 mm	200 mm	346.25 mm

We know that the deflection refers to the lateral deflection at any point in the structure relative to the ground. Incremental deflection or interstorey deflection refers to the lateral deflection of a storey relative to the one just below it.

Structural Separation:

From Division B, Sentence 4.1.8.14.(1)

$$Separation_{minimum} = \sqrt{78^2 + 146.25^2} = 165.75\,mm$$

Exercise 7-10

Location	h_x	h_n	$A_x=1+2h_x/h_n$
9th	2.8	2.8+9(3.5)= 34.3	1.16
6th	2.8	2.8+6(3.5)= 23.8	1.24
Ground	2.8	2.8	3

Question 1

From SB-1, Table 1.2:

$S_a(0.2) = 0.66$

From Division B, Table 4.1.8.4.B:

$F_a = 1.1$

From Division B, Table 4.1.8.5.:

$I_E = 1.0$

From Sentence 4.1.8.17.(2):

$I_E F_a S_a(0.2) = 1.0 \times 1.1 \times 0.66 = 0.73 > 0.35$

therefore Categories 6 through 21 of Table 4.1.8.17. are not exempt.

From Table 4.1.8.17.:

$C_p = 1.0$

$A_r = 1.0$

$R_p = 2.5$

From Sentence 4.1.8.17.(1):

S_p minimum = 0.7

S_p maximum = 4.0

$$S_p = \frac{C_p A_r A_x}{R_p}$$

for 9th floor $S_p = 0.46$ - use 0.7

for 6th floor $S_p = 0.50$ - use 0.7

for Ground floor $S_p = 1.12$

Location	W_p	S_p	V_p
9th	2.4 kN	0.7	0.37 kN
6th	2.4 kN	0.7	0.37 kN
Ground	2.4 kN	1.12	0.59 kN

	Question 2 As in question #1, category 12 components are not exempt. From Table 4.1.8.17.: $C_p = 1.5$ $A_r = 2.5$ $R_p = 2.5$ Calculation: $h_x = 1.5$ m $h_n = 10(3.5) + 1.5 = 36.5$ m $A_x = 1 + 2(1.5)/36.5 = 1.08$ From Sentence 4.1.8.17.(1): S_p minimum = 0.7 S_p maximum = 4.0 $S_p = \frac{C_p A_r A_x}{R_p}$ S_p = 1.5 X 2.5 X 1.08/2.5 = 1.62 W_p = 100 kN V_p = 0.3 X 1.1 X 0.66 X 1.0 X 1.62 X 100 = 35.28 kN
Module 8 Other Structural Loads and Special Structures	
Exercise 8-1	Question 1 **True** (ref. Div. A. Article 1.4.1.2) Question 2 **Yes** (ref. Sentence 3.1.10.1.(1)) Question 3 **Answer = b**), as per Sentence 3.1.10.1.(3) Question 4 Support by wood beam would not be acceptable, since supports must be non-combustible construction, as required by Sentence 3.1.10.1.(3)
Exercise 8-2	Question 1 **Answer = d),** as per Sentence 4.1.5.18.(1)

	Question 2 **Answer = c)**, as per Sentence 4.1.5.18.(2)
Exercise 8-3	Question 1 **Answer = c)**, as per Sentence 3.4.6.4.(9) Question 2 **Answer = d)**, as per Sentence OBC 3.4.6.4.(3)
Exercise 8-4	Question 1 **Answer = c)** Question 2 **Answer = d)** Question 3 **Answer = b)** Question 4 **Answer = a)**
Exercise 8-5	Question 1 **Answer = c)**, as per Article 3.7.4.14
Exercise 8-6	Question 1 **True**, as per Clause 3.7.2.2.(3)(b) Question 2 **False**, Per Sentence 3.7.2.2.(3) Question 3 **True**, as per Sentence 3.7.2.2.(3) Question 4 **True**, as per OBC 3.7.2.2.(4) Question 5 a. Group C major occupancy **apartment** building; Sentence 3.7.2.2.(1) b. Window is within a ***dwelling unit;*** Sentences 3.7.2.2.(2) and (4) c. Base of fixed window is less than **1000 mm** above floor level; Sentence 3.7.2.2.(2) d. Fixed window is not otherwise protected by a **guard** that extends at least **1000 mm** above floor level; Sentence 3.7.2.2.(2) e. An exterior **balcony** is not constructed for the full length of the **window;** Sentence 3.7.2.2.(4)

Exercise 8-7	Question 1 **Answer = d),** as per Sentence 4.1.5.15.(5) Question 2 a. 0.75 kN/m horiz per Clause 4.1.5.15.(1)(c) b. 1.5 kN/m vertical per Sentence 4.1.5.15.(4) c. 1.0 kN per Clause 4.1.5.15.(1)(c) d. 0.5 kN per Sentence 4.1.5.15.(2) Question 3 **Answer: d)**, as per Article 4.1.5.17 Question 4 **Answer: d)**, as per Articles 4.1.5.15 and 4.1.5.16
Exercise 8-8	Question 1 **Answer = b)** Question 2 **Answer = a)** Question 3 **Answer = c)**, as per OBC 4.1.5.12.(4) Question 4 **Answer = c)** as per Article 4.1.5.12
Exercise 8-9	Question 1 **Answer = c)**, as per Sentence 4.4.1.1.(1) Question 2 **Answer = b)**, as per Sentence 4.4.1.1.(1) Question 3 **Answer = c)**, as per Sentence 4.4.2.1.(1) Question 4 **Answer = TRUE**, as per Sentence 4.4.3.1.(1)
Module 9 Foundations Designed using Part 4	
Exercise 9-1	Question 1 **Answer = d),** as per Article 4.2.4.2 Question 2 **Answer = c),** as per Article 4.2.4.2

	Question 3 **Answer = b)**, as per Sentence 4.2.4.1.(1) Question 4 Per Sentence 4.2.2.1(1): A subsurface investigation, including groundwater conditions, shall be carried out, by or under the direction of a person having knowledge and experience in planning and executing such investigations to a degree appropriate for the building and its use, the ground and the surrounding site conditions.
Exercise 9-2	Question 1 **Answer = c)**, as per Article 4.2.3.2 Question 2 **Answer = b)**, as per Article 4.2.3.8 Question 3 a. Concrete subject to chemical attack - Article 4.2.3.6 b. Steel tendons – Article 4.2.3.9 Question 4 **Answer = c)**, as per Articles 4.2.3.3 and 4.3.2.1 Question 5 **Answer = d)**, as per Articles 4.2.3.4, 4.2.3.6 and 4.2.3.10
Exercise 9-3	Question 1 a. Div B - Sentence 4.2.5.1.(1) b. Div B - Sentence 4.2.4.1.(1) c. Div B - Sentence 4.2.1.1.(1) d. Div C - Sentence 1.2.1.1.(5) Question 2 **Answer = d)**, as per Article 4.2.5.5 Question 3 **Answer = c)**, as per Article 4.2.5.4 Question 4 a. Adjacent buildings – Sentence 4.2.5.2.(1) b. The integrity excavation and its supports - Sentence 4.2.5.2.(2) c. Protect against loss of ground – Sentence 4.2.5.6.(1)

	Question 5 a. Construction activity b. Frost c. Wind d. Rain e. Groundwater (OBC 4.2.5.5) Question 6 **Answer = a)**, as per Article 4.2.5.8
Exercise 9-4	Question 1 **Answer = c)**, as per Sentence 4.2.4.1.(1) Question 2 **Answer = b)**, as per Article 4.2.4.10 Question 3 **Answer = c)**, as per Article 4.2.4.14 → Article 4.3.3.1 and Article 4.2.3.5 → Subsection 4.3.3 Question 4 **Answer = c)**, as per Sentence 4.2.4.1.(1) Question 5 **Answer = d)**, as per Sentences 4.2.4.1(2) to (5) Question 6 **Answer = d)**, as per Article 4.2.4.4 Question 7 **Answer = c)**, as per Article 4.2.4.13 Question 8 a. Foundation on or near sloping ground b. Loads are eccentric or inclined to foundation units c. Applied loads are dynamic d. Hydrostatic uplift e. Groundwater level changes on adjacent properties f. Permafrost g. Swelling or shrinking soils h. Expansive or deteriorating rock
Exercise 9-5	Question 1 **Answer = d)**, as per Article 4.2.6.2 Question 2 **Answer = d)**

	Question 3 **Answer = c)**, as per Articles 4.2.6.3 Question 4 **Answer = d)**, as per Article 4.2.6.4
Exercise 9-6	Question 1 **Answer = c)**, as per Article 4.2.7.1 Question 2 **Answer = c)**, as per Sentence 4.2.7.2.(2) Question 3 **Answer = c)**, as per Sentences 4.2.7.2.(4) and (5) Question 4 a. Geotechnical considerations per subsurface investigation b. Installation methods c. Degree of inspection and testing d. Spacing and group effects e. Lateral support conditions f. Driving, handling and testing stresses Question 5 **Answer = c),** as per OBC 4.2.7.4 Question 6 **Answer = d)**, as per Article 4.2.7.6
Exercise 9-7	Question 1 **Answer = YES**, as per Article 4.2.8.2 Question 2 **Answer =** YES, as per Article 4.2.8.2
Exercise 9-8	Question 1 **Answer = c)**, as per Sentence 4.2.2.2.(1) Question 2 **Answer = c)**, as per Sentence 4.2.2.2.(2) Question 3 a. Soil, rock or groundwater is found to be different than that used in the design (Sentence 4.2.2.3.(1)) b. Climatic or other conditions have changed the properties of the soil, rock or ground water (Sentence 4.2.2.3.(2))

	c. Damaged foundation units (Articles 4.2.6.4 and 4.2.7.6) Question 4 **Answer = a)**, as per Sentences 4.2.2.3.(1) and (2) Question 5 **Answer = YES**, as per Article 4.2.1
Module 10 General Structural Requirements- Part 9 Buildings	
Exercise 10-1	Question 1 *Building height* means the number of *storeys* contained between the roof and the floor of the *first storey*. *Building area* means the greatest horizontal area of a *building* above *grade* within the outside surface of exterior walls **or** within the outside surface of exterior walls and the centre line of *firewalls*. *Residential occupancy* means the *occupancy* or use of a *building* or part thereof by persons for whom sleeping accommodation is provided but who are not harboured or detained to receive medical care or treatment or are not involuntarily detained. *Mercantile occupancy* means the *occupancy* or use of a *building* or part thereof for the displaying or selling of retail goods, wares or merchandise. Reference: Article 1.4.1.2 of Division A Question 2 **Answer = d)** Question 3 **Answer = a)**
Exercise 10-2	Question 1 **Answer = c)**, as per Sentence 9.4.2.1.(1)(b) Question 2 Using Table 1.2 of the Supplementary Standard SB-1, and Article 9.4.2.2: a. London 1.45kPa b. Parry Sound 1.94 kPa c. Sault Ste Marie 2.11kPa d. Toronto 1.0kPa (min) e. Wawa 2.66kPa

	Question 3 Answer = 1.0 kPa, as per Sentence 9.4.2.2.(2) Question 4 **Answer = c)**, as per Sentence 9.4.2.3.(1) Question 5 Answer = L/360, as per Article 9.4.3.1
Exercise 10-3	Question 1 **Answer = d)**, as per Sentence 9.3.2.1.(1) Question 2 Answers, per Table 9.3.2.1: a. Plank frame construction for loadbearing members b. Roof sheathing c. Subflooring Question 3 Answers per Sentence 9.3.2.4.(1) : a. Manufacturer b. Standard to which produced c. Suitable for Exterior use Question 4 **Answer = b)**, as per Article 9.3.2.5 Question 5 **Answer = a)**, as per Article 9.3.2.9

Exercise 10-4	Question 1 Answer: CAN/CSA-A438 "Concrete Construction for Housing and Small Buildings" Reference: Sentence 9.3.1.1.(1) Question 2 Answer: Any four of the following: • Sand • Gravel • Crushed rock • Crushed air-cooled blast furnace slag • Expanded shale • Expanded clay Reference: Clause 9.3.1.4.(1)(a) Question 3 Answer: 5% to 8%, as per Sentence 9.3.1.6.(2) Question 4 a. Ensure temperature of concrete being placed is above 10°C and less than 25°C b. Maintain concrete temperature at or above 10°C for 72 hours c. Ensure no frozen material or ice is used in concrete. (Article 9.3.1.9.(2)) d. Also note that the soil should not be frozen, as upon thawing, unacceptable settlement may occur. (Article 9.12.1.3) Question 5 Answer = 0.7 Reference: Clause 9.3.1.7.(1)(c)
Module 11 Footings- Part 9 Buildings	
Exercise 11-1	Question 1 a. Unacceptable. Soil bearing pressure less then 75 kPa. 9.15.1.1.(1)(b) b. Unacceptable. Greater then two storeys in height. 9.15.1.1.(1)(c)

	c. Unacceptable. Does not identify that there is no surcharge. Otherwise acceptable. 9.15.1.1.(1)(a) d. Unacceptable. Requires design under Part 4. 9.15.1.2 e. Correct f. Incorrect
Exercise 11-2	Question 1 Answer: Referencing Figure 11:1, the lower *soil* stratum is more than twice the footing width below the founding level therefore a bearing value of 150 kPa would be used.(per Article 9.4.4.2) Question 2 Loose sand 50 NO Compact silt 100 YES Soft clay 40 NO Firm clay 75 YES Loose gravel 50 NO Sensitive Clay N/a NO Question 3 **Answer = c)**, as per Article 9.4.4.3 and Sentence 9.15.3.4(3)
Exercise 11-3	Question 1 **Answer = b)** Question 2 Difference of elevation = 3.2 – 2.4 = 0.8 m, Therefore, required horizontal separation = twice the rise = 1.6 m. (ref. Per Article 1.2.1.1.(5) Div. C)
Exercise 11-4	Question 1 a. **Answer = iii**, as per Table 9.15.3.4 and Article 9.15.3.6.(1) b. **Answer = iii**, as per Table 9.15.3.4 and 9.15.3.4.(2) c. **Answer = ii**, as per Table 9.15.3.4 and 9.15.3.5.(1)(c) Question 3 Per Table 9.15.3.3, area = 0.75 m^2

	Question 3 **Answer = d)**, as per Sentence 9.37.3.2.(1)
Exercise 18-2	Question 1 Answer = **None**, as per Sentences 9.39.3.3.(1) and 9.39.1.1.(1) Question 2 Per Sentence 9.39.3.3.(1), anchorage shall be in conformance with the manufacturer's installation instructions Question 3 **Answer = b)**, as per Article 9.39.3.3
Exercise 18-3	Question 1 **Answer = c)**, as per Reference 9.36.2.2(2)(a)
Module 19 Farm Buildings	
Exercise 19-1	Question 1 **Answer = a),** as per Div. A, Article 1.3.1.2.(4) Question 2 **Answer = c),** as per Div. A, Sentence 1.3.1.2.(4) Question 3 **Answer = b),** as per Div. A, Article 1.4.1.2 Question 4 Answer = From Q3, need 40 m^2 of floor area per person, therefore minimum required floor area is 40*16 = 640 m^2
Exercise 19-2	Question 1 **Answer = b)**, as per Table 1.3.3.N Question 2 **Answer = c)**, as per Article 1.1.2 of SB-11 Question 3 **Answer = c),** as per Table 1.3.2.H Question 4 **Answer = d)**, as per Table 1.3.2.H

	Question 5 **Answer = d)**, per Clause 9.4.4.4.(1)(c)
Exercise 19-3	Question 1 **Answer = c)**
Module 20 Renovations – Part 11	
Exercise 20-1	Question 1 **Answer = c)**, as per Division A, Sentence 1.1.2.6.(1) Question 2 **Answer = c)**, as per Division A, Sentence 1.1.2.6.(2)
Exercise 20-2	Question 1 **Answer = a)** Question 2 The performance level of the building after the material alteration or repair shall be at least equal to the performance level prior to the material alteration or repair. Ref. Sentence 11.3.1.1.(1)
Exercise 20-3	Question 1 **Answer = a)** Question 2 **Answer = a)**, as per Clause 11.4.2.1.(1) (c) Question 3 **Answer = c)**
Exercise 20-4	Question 1 **Answer = a)**, as per Sentence 11.4.3.1.(1) Question 2 **Answer = b)**
Exercise 20-5	Question 1 **Answer = a)**, as per CA B76 (in Table 11.5.1.1.B) Question 2 Answer: **Do nothing**, as per CA B48 Question 3 **Answer = d)**, as per Table 11.5.1.1.C

	Question 4 Authority for remedial measures: Compensating construction, as indicated in Clause 11.4.3.2.(1)(a), must be provided since the performance level would be reduced under Sentence 11.4.2.1.(1). There is no compliance alternative specified in Table 11.5.1.1.D/E for live loads in Subsection 4.1.5.

Ontario